Package ‘rayrender’

November 23, 2021

Type Package

Title Build and Raytrace 3D Scenes

Version 0.23.6

Date 2021-11-23

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Description Render scenes using pathtracing. Build 3D scenes out of spheres, cubes, planes, disks, triangles, cones, curves, line segments, cylinders, ellipsoids, and 3D models in the 'Wavefront' OBJ file format or the PLY Polygon File Format. Supports several material types, textures, multicore rendering, and tone-mapping. Based on the ``Ray Tracing in One Weekend'' book series. Peter Shirley (2018) <https://raytracing.github.io>.

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Imports Rcpp (>= 1.0.0), parallel, tibble, magrittr, purrr, png, raster, decido, rayimage (>= 0.6.2), stats, progress

Suggests sf, spData, dplyr, Rvcg, testthat (>= 3.0.0)

LinkingTo Rcpp, RcppThread, progress, spacefillr

URL https://www.rayrender.net, https://github.com/tylermorganwall/rayrender

RoxygenNote 7.1.2

SystemRequirements C++11

Config/testthat/edition 3

NeedsCompilation yes

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Repository CRAN

Date/Publication 2021-11-23 09:10:02 UTC

R topics documented:

`add_object` *Add Object*

Description

Add Object

Usage

```
add_object(scene, objects)
```

Arguments

`scene`	Tibble of pre-existing object locations and properties.
`objects`	A tibble row or collection of rows representing each object.

Value

Tibble of object locations and properties.

Examples

```
#Generate the ground and add some objects
scene = generate_ground(depth=-0.5,material = diffuse(checkercolor="blue")) %>%
  add_object(cube(x=0.7,
              material=diffuse(noise=5,noisecolor="purple",color="black",noisephase=45),
                  angle=c(0,-30,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=metal(color="gold")))

render_scene(scene,parallel=TRUE)
```

animate_objects *Animate Objects*

Description

This function animates an object between two states. This animates objects separately from the transformations set in ‘group_objects()‘ and in the object transformations themselves. This creates motion blur, controlled by the shutter open/close options in ‘render_scene()‘.

Usage

```
animate_objects(
  scene,
  start_time = 0,
  end_time = 1,
  start_pivot_point = c(0, 0, 0),
  start_position = c(0, 0, 0),
  start_angle = c(0, 0, 0),
  start_order_rotation = c(1, 2, 3),
  start_scale = c(1, 1, 1),
  start_axis_rotation = NA,
  end_pivot_point = c(0, 0, 0),
  end_position = c(0, 0, 0),
  end_angle = c(0, 0, 0),
  end_order_rotation = c(1, 2, 3),
  end_scale = c(1, 1, 1),
  end_axis_rotation = NA
)
```

Arguments

`scene`	Tibble of pre-existing object locations.
`start_time`	Default ‘0‘. Start time of movement.
`end_time`	Default ‘1‘. End time of movement.
`start_pivot_point`	Default ‘c(0,0,0)‘. The point about which to pivot, scale, and move the objects.
`start_position`	Default ‘c(0,0,0)‘. Vector indicating where to offset the objects.
`start_angle`	Default ‘c(0,0,0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`start_order_rotation`	Default ‘c(1,2,3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`start_scale`	Default ‘c(1,1,1)‘. Scaling factor for x, y, and z directions for all objects.
`start_axis_rotation`	Default ‘NA‘. Provide an axis of rotation and a single angle (via ‘angle‘) of rotation

`end_pivot_point`	Default ‘c(0,0,0)‘. The point about which to pivot, scale, and move the group.
`end_position`	Default ‘c(0,0,0)‘. Vector indicating where to offset the objects.
`end_angle`	Default ‘c(0,0,0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`end_order_rotation`	Default ‘c(1,2,3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`end_scale`	Default ‘c(1,1,1)‘. Scaling factor for x, y, and z directions for all objects.
`end_axis_rotation`	Default ‘NA‘. Provide an axis of rotation and a single angle (via ‘angle‘) of rotation around that axis.

Value

Tibble of animated object.

Examples

```
#Render a pig

generate_studio() %>%
  add_object(pig(y=-1.2,scale=0.5,angle=c(0,-70,0)))%>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue")

#Render a moving pig
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_position = c(-0.1,0,0), end_position = c(0.1,0.2,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10)


#Render a shrinking pig
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_scale = c(1,1,1), end_scale = c(0.5,0.5,0.5))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10)

#Render a spinning pig
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10)


#Shorten the open shutter time frame
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10,
               shutteropen=0.4, shutterclose = 0.6)

#Change the time frame when the shutter is open
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10,
               shutteropen=0, shutterclose = 0.1)

#Shorten the time span in which the movement occurs (which, in effect,
#increases the speed of the transition).
generate_studio() %>%
  add_object(
    animate_objects(start_time = 0, end_time=0.1,
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=256,sample_method = "sobol_blue",clamp_value = 10,
               shutteropen=0, shutterclose = 0.1)
```

`arrow` *Arrow Object*

Description

Composite object (cone + segment)

Usage

```
arrow(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius_top = 0.2,
  radius_tail = 0.1,
  tail_proportion = 0.5,
  direction = NA,
  from_center = TRUE,
  material = diffuse(),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`start`	Default ‘c(0, 0, 0)‘. Base of the arrow, specifying ‘x‘, ‘y‘, ‘z‘.
`end`	Default ‘c(0, 1, 0)‘. Tip of the arrow, specifying ‘x‘, ‘y‘, ‘z‘.
`radius_top`	Default ‘0.5‘. Radius of the top of the arrow.
`radius_tail`	Default ‘0.2‘. Radius of the tail of the arrow.
`tail_proportion`	Default ‘0.5‘. Proportion of the arrow that is the tail.
`direction`	Default ‘NA‘. Alternative to ‘start‘ and ‘end‘, specify the direction (via a length-3 vector) of the arrow. Arrow will be centered at ‘start‘, and the length will be determined by the magnitude of the direction vector.
`from_center`	Default ‘TRUE‘. If orientation specified via ‘direction‘, setting this argument to ‘FALSE‘ will make ‘start‘ specify the bottom of the cone, instead of the middle.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the cone. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cone in the scene.

Examples

```
#Draw a simple arrow from x = -1 to x = 1

generate_studio() %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), material=glossy(color="red"))) %>%
  add_object(sphere(y=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10,  samples=400)

#Change the proportion of tail to top
generate_studio(depth=-2) %>%
  add_object(arrow(start = c(-1,-1,0), end = c(1,-1,0), tail_proportion = 0.5,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), tail_proportion = 0.75,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,1,0), end = c(1,1,0), tail_proportion = 0.9,
                   material=glossy(color="red"))) %>%
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=25,  samples=400)

#Change the radius of the tail/top segments
generate_studio(depth=-1.5) %>%
  add_object(arrow(start = c(-1,-1,0), end = c(1,-1,0), tail_proportion = 0.75,
                   radius_top = 0.1, radius_tail=0.03,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), tail_proportion = 0.75,
                   radius_top = 0.2, radius_tail=0.1,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,1,0), end = c(1,1,0), tail_proportion = 0.75,
                   radius_top = 0.3, radius_tail=0.2,
                   material=glossy(color="red"))) %>%
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=400)


#We can also specify arrows via a midpoint and direction:
generate_studio(depth=-1) %>%
  add_object(arrow(start = c(-1,-0.5,0), direction = c(0,0,1),
                   material=glossy(color="green"))) %>%
  add_object(arrow(start = c(1,-0.5,0), direction = c(0,0,-1),
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(0,-0.5,1), direction = c(1,0,0),
                   material=glossy(color="yellow"))) %>%
  add_object(arrow(start = c(0,-0.5,-1), direction = c(-1,0,0),
                   material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=400,
               lookfrom=c(0,5,10), lookat=c(0,-0.5,0), fov=16)

#Plot a 3D vector field for a gravitational well:

r = 1.5
theta_vals = seq(0,2*pi,length.out = 16)[-16]
phi_vals = seq(0,pi,length.out = 16)[-16][-1]
arrow_list = list()
counter = 1
for(theta in theta_vals) {
  for(phi in phi_vals) {
    rval = c(r*sin(phi)*cos(theta),r*cos(phi),r*sin(phi)*sin(theta))
    arrow_list[[counter]] = arrow(rval, direction = -1/2*rval/sqrt(sum(rval*rval))^3,
                              tail_proportion = 0.66, radius_top=0.03, radius_tail=0.01,
                                 material = diffuse(color="red"))
    counter = counter + 1
  }
}
vector_field = do.call(rbind,arrow_list)
sphere(material=diffuse(noise=1,color="blue",noisecolor="darkgreen")) %>%
  add_object(vector_field) %>%
  add_object(sphere(y=0,x=10,z=5,material=light(intensity=200))) %>%
  render_scene(fov=20, ambient=TRUE, samples=400,
               backgroundlow="black",backgroundhigh="white")
```

`bezier_curve` *Bezier Curve Object*

Description

Bezier curve, defined by 4 control points.

Usage

```
bezier_curve(
  p1 = c(0, 0, 0),
  p2 = c(-1, 0.33, 0),
  p3 = c(1, 0.66, 0),
  p4 = c(0, 1, 0),
  x = 0,
  y = 0,
  z = 0,
  width = 0.1,
  width_end = NA,
  u_min = 0,
  u_max = 1,
  type = "cylinder",
  normal = c(0, 0, -1),
  normal_end = NA,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

p1	Default ‘c(0,0,0)‘. First control point. Can also be a list of 4 length-3 numeric vectors or 4x3 matrix/data.frame specifying the x/y/z control points.

p2	Default ‘c(-1,0.33,0)‘. Second control point.
p3	Default ‘c(1,0.66,0)‘. Third control point.
p4	Default ‘c(0,1,0)‘. Fourth control point.
x	Default ‘0‘. x-coordinate offset for the curve.
y	Default ‘0‘. y-coordinate offset for the curve.
z	Default ‘0‘. z-coordinate offset for the curve.
width	Default ‘0.1‘. Curve width.
width_end	Default ‘NA‘. Width at end of path. Same as ‘width‘, unless specified.
u_min	Default ‘0‘. Minimum parametric coordinate for the curve.
u_max	Default ‘1‘. Maximum parametric coordinate for the curve.
type	Default ‘cylinder‘. Other options are ‘flat‘ and ‘ribbon‘.
normal	Default ‘c(0,0,-1)‘. Orientation surface normal for the start of ribbon curves.
normal_end	Default ‘NA‘. Orientation surface normal for the start of ribbon curves. If not specified, same as ‘normal‘.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
#Generate the default curve:

generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=500)

#Change the control points to change the direction of the curve. Here, we place spheres
#at the control point locations.
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(material=diffuse(color="red"))) %>%
  add_object(sphere(radius=0.075,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,x=-1,y=0.33,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,x=1,y=0.66,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,y=1,material=glossy(color="green"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=15,
               samples=500)

#We can make the curve flat (always facing the camera) by setting the type to `flat`
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(type="flat", material=glossy(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=500)


#We can also plot a ribbon, which is further specified by a start and end orientation with
#two surface normals.
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(type="ribbon", width=0.2,
                   p1 = c(0,0,0), p2 = c(0,0.33,0), p3 = c(0,0.66,0), p4 = c(0.3,1,0),
                   normal_end = c(0,0,1),
                   material=glossy(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=500)


#Create a single curve and copy and rotate it around the y-axis to create a wavy fountain effect:
scene_curves = list()
for(i in 1:90) {
  scene_curves[[i]] = bezier_curve(p1 = c(0,0,0),p2 = c(0,5-sinpi(i*16/180),2),
                            p3 = c(0,5-0.5 * sinpi(i*16/180),4),p4 = c(0,0,6),
                            angle=c(0,i*4,0), type="cylinder",
                            width = 0.1, width_end =0.1,material=glossy(color="red"))
}
all_curves = do.call(rbind, scene_curves)
generate_ground(depth=0,material=diffuse(checkercolor="grey20")) %>%
  add_object(all_curves) %>%
  add_object(sphere(y=7,z=0,x=0,material=light(intensity=100))) %>%
  render_scene(lookfrom = c(12,20,50),samples=100,
               lookat=c(0,1,0), fov=15, clamp_value = 10)
```

cone *Cone Object*

Description

Cone Object

Usage

```
cone(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 0.5,
  direction = NA,
  from_center = TRUE,
  material = diffuse(),
  angle = c(0, 0, 0),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`start`	Default ‘c(0, 0, 0)‘. Base of the cone, specifying ‘x‘, ‘y‘, ‘z‘.
`end`	Default ‘c(0, 1, 0)‘. Tip of the cone, specifying ‘x‘, ‘y‘, ‘z‘.
`radius`	Default ‘1‘. Radius of the bottom of the cone.
`direction`	Default ‘NA‘. Alternative to ‘start‘ and ‘end‘, specify the direction (via a length-3 vector) of the cone. Cone will be centered at ‘start‘, and the length will be determined by the magnitude of the direction vector.
`from_center`	Default ‘TRUE‘. If orientation specified via ‘direction‘, setting this argument to ‘FALSE‘ will make ‘start‘ specify the bottom of the cone, instead of the middle.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Rotation angle. Note: This will change the ‘start‘ and ‘end‘ coordinates.
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the cone. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cone in the scene.

Examples

```
#Generate a cone in a studio, pointing upwards:

generate_studio() %>%
 add_object(cone(start=c(0,-1,0), end=c(0,1,0), radius=1,material=diffuse(color="red"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
 render_scene(samples=400,clamp_value=10)

 #Change the radius, length, and direction
generate_studio() %>%
 add_object(cone(start=c(0,0,0), end=c(0,-1,0), radius=0.5,material=diffuse(color="red"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
 render_scene(samples=400,clamp_value=10)

#Give custom start and end points (and customize the color/texture)
generate_studio() %>%
 add_object(cone(start=c(-1,0.5,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="red"))) %>%
 add_object(cone(start=c(1,0.5,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="green"))) %>%
 add_object(cone(start=c(0,1,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="orange"))) %>%
 add_object(cone(start=c(-1,-0.5,0), end=c(1,-0.5,0), radius=0.25,
   material = diffuse(color="red",gradient_color="green"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
 render_scene(samples=400,clamp_value=10)


#Specify cone via direction and location, instead of start and end positions
#Length is derived from the magnitude of the direction.
gold_mat = microfacet(roughness=0.1,eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661))
generate_studio() %>%
  add_object(cone(start = c(-1,0,0), direction = c(-0.5,0.5,0), material = gold_mat)) %>%
  add_object(cone(start = c(1,0,0), direction = c(0.5,0.5,0), material = gold_mat)) %>%
  add_object(cone(start = c(0,0,-1), direction = c(0,0.5,-0.5), material = gold_mat)) %>%
  add_object(cone(start = c(0,0,1), direction = c(0,0.5,0.5), material = gold_mat)) %>%
  add_object(sphere(y=5,material=light())) %>%
  add_object(sphere(y=3,x=-3,z=-3,material=light(color="red"))) %>%
  add_object(sphere(y=3,x=3,z=-3,material=light(color="green"))) %>%
  render_scene(lookfrom=c(0,4,10), clamp_value=10, samples=400)

 #Render the position from the base, instead of the center of the cone:
 noise_mat = material = glossy(color="purple",noisecolor="blue", noise=5)
 generate_studio() %>%
  add_object(cone(start = c(0,-1,0), from_center = FALSE, radius=1, direction = c(0,2,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(-1.5,-1,0), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(1.5,-1,0), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(0,-1,1.5), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(0,4,10), clamp_value=10,fov=25, samples=400)
```

csg_box *CSG Box*

Description

CSG Box

Usage

```
csg_box(x = 0, y = 0, z = 0, width = c(1, 1, 1), corner_radius = 0)
```

Arguments

`x`	Default ‘0‘. An x-coordinate on the box.
`y`	Default ‘0‘. A y-coordinate on the box.
`z`	Default ‘0‘. A z-coordinate on the box
`width`	Default ‘c(1,1,1)‘. Length-3 vector describing the x/y/z widths of the box
`corner_radius`	Default ‘0‘. Radius if rounded box.

Value

List describing the box in the scene.

Examples

```
#Generate a box
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_box(), material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10,lookfrom=c(7,3,7))

#Change the width
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_box(width = c(2,1,0.5)), material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10,lookfrom=c(7,3,7))

#Subtract two boxes to make stairs
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_box(),
    csg_box(x=0.5,y=0.5,width=c(1,1,1.1)),operation="subtract"),
   material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10,lookfrom=c(7,3,7),fov=13)
```

`csg_capsule` *CSG Capsule*

Description

CSG Capsule

Usage

```
csg_capsule(start = c(0, 0, 0), end = c(0, 1, 0), radius = 1)
```

Arguments

`start`	Default ‘c(0, 0, 0)‘. Start point of the capsule, specifying ‘x‘, ‘y‘, ‘z‘.
`end`	Default ‘c(0, 1, 0)‘. End point of the capsule, specifying ‘x‘, ‘y‘, ‘z‘.
`radius`	Default ‘1‘. Capsule radius.

Value

List describing the capsule in the scene.

Examples

```
#Generate a basic capsule:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_capsule(radius=0.5),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10,fov=20)

#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_capsule(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))

#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_capsule(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_capsule(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.25)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))

#Render a capsule in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
 csg_capsule(start = c(555/2-100,555/2,555/2), end = c(555/2+100,555/2,555/2), radius=100),
   material=glossy(color="dodgerblue4"))) %>%
  render_scene(clamp_value=10)
```

csg_combine *CSG Combine*

Description

Note: Subtract operations aren't commutative: the second object is subtracted from the first.

Usage

```
csg_combine(object1, object2, operation = "union", radius = 0.5)
```

Arguments

object1	First CSG object
object2	Second CSG object
operation	Default 'union'. Can be 'union', 'subtract', 'intersection', 'blend', 'subtract-blend', or 'mix'.
radius	Default '0.5'. Blending radius.

Value

List describing the combined csg object in the scene.

Examples

```
#Combine two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="union"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Subtract one sphere from another:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtract"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))
```

```
#Get the intersection of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="intersection"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Get the blended union of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="blend"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Get the blended subtraction of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtractblend"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Change the blending radius:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="blend", radius=0.2),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Change the subtract blending radius:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtractblend", radius=0.2),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-3,5,10))

#Get the mixture of various objects:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(),
     csg_box(), operation="mix"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(csg_combine(
    csg_box(),
    csg_torus(), operation="mix"),z=-2.5),
  material=glossy(color="red"))) %>%
  add_object(csg_object(csg_translate(csg_combine(
    csg_pyramid(),
    csg_box(), operation="mix"),z=2.5),
  material=glossy(color="green"))) %>%
  add_object(sphere(y=10,x=-5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(-15,10,10))
```

csg_cone *CSG Cone*

Description

CSG Cone

Usage

```
csg_cone(start = c(0, 0, 0), end = c(0, 1, 0), radius = 0.5)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘1‘. Radius of the bottom of the cone.

Value

List describing the box in the scene.

Examples

```
#Generate a basic cone:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_cone(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10,fov=20)

#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))

#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_cone(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.2)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))

#Render a glass cone in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
    csg_cone(start = c(555/2,0,555/2), end = c(555/2,555/2+100,555/2), radius=100),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10)
```

---

csg_cylinder *CSG Cylinder*

Description

CSG Cylinder

Usage

```
csg_cylinder(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 1,
  corner_radius = 0
)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the cylinder, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cylinder, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘1‘. Cylinder radius.
corner_radius	Default ‘0‘. Radius if rounded cylinder.

Value

List describing the cylinder in the scene.

Examples

```
#Generate a basic cylinder:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_cylinder(radius=0.25),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10,fov=20)

#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_cylinder(start = c(-1,0.5,-2), end = c(1,0.5,-2),
    radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))

#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_cylinder(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_cylinder(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.25)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))

#Render a red marble cylinder in a Cornell box
generate_cornell(light=FALSE) %>%
  add_object(csg_object(
    csg_cylinder(start = c(555/2,0,555/2), end = c(555/2,350,555/2), radius=100),
    material=glossy(color="darkred",noisecolor="white",noise=0.03))) %>%
    add_object(sphere(y=555,x=5,z=5, radius=5,
               material=light(intensity=10000,
                       spotlight_focus = c(555/2,555/2,555/2),spotlight_width = 45))) %>%
  render_scene(clamp_value=4)
```

`csg_ellipsoid` *CSG Ellipsoid*

Description

CSG Ellipsoid

Usage

```
csg_ellipsoid(x = 0, y = 0, z = 0, axes = c(0.5, 1, 0.5))
```

Arguments

x	Default ‘0‘. x-coordinate on the ellipsoid.

y	Default ‘0‘. y-coordinate on the ellipsoid.
z	Default ‘0‘. z-coordinate on the ellipsoid.
axes	Default ‘c(0.5,1,0.5)‘. Ellipsoid principle axes.

Value

List describing the ellipsoid in the scene.

Examples

```
#Generate a basic ellipsoid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_ellipsoid(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10,fov=20)

#Three different ellipsoids:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_group(list(
   csg_ellipsoid(x=-1.2, axes = c(0.2,0.5,0.5)),
   csg_ellipsoid(x=0, axes = c(0.5,0.2,0.5)),
   csg_ellipsoid(x=1.2, axes = c(0.5,0.5,0.2)))),
   material=glossy(color="red"))) %>%
 render_scene(clamp_value=10,fov=20,lookfrom=c(0,5,10))

#Generate a glass ellipsoid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_ellipsoid(),material=dielectric(attenuation = c(1,1,0.3)))) %>%
  render_scene(clamp_value=10,fov=20)

#Generate a glass ellipsoid in a Cornell box:
generate_cornell() %>%
  add_object(csg_object(csg_ellipsoid(x=555/2,y=555/2,z=555/2,axes=c(100,150,200)),
    material=dielectric(attenuation = c(1,0.3,1)/200))) %>%
  render_scene(clamp_value=10)
```

---

csg_elongate *CSG Elongate*

Description

This operation elongates an existing CSG object in a direction.

Usage

```
csg_elongate(object, x = 0, y = 0, z = 0, elongate = c(0, 0, 0), robust = TRUE)
```

Arguments

`object`	CSG object.
`x`	Default ‘0‘. Center of x-elongation.
`y`	Default ‘0‘. Center of y-elongation.
`z`	Default ‘0‘. Center of z-elongation.
`elongate`	Default ‘c(0,0,0)‘ (no elongation). Elongation amount.
`robust`	Default ‘TRUE‘. ‘FALSE‘ switches to a faster (but less robust in 2D) method.

Value

List describing the triangle in the scene.

Examples

```
#Elongate a sphere to create a capsule in 1D or a rounded rectangle in 2D:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_sphere(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_sphere(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_sphere(z=2),z=2, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10,fov=40,lookfrom=c(0,10,10))

#Elongate a torus:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_torus(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_torus(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_torus(z=2),z=2, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10,fov=40,lookfrom=c(0,10,10))

#Elongate a cylinder:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_cylinder(start=c(-3,0,-3), end = c(-3,1,-3)),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_cylinder(start=c(3,0,-3), end = c(3,1,-3)), x=3, z=-3,
                      elongate = c(0.8,0,0)),
                      material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_cylinder(start=c(0,0,3), end = c(0,1,3)), z=3,
                      elongate = c(0.8,0,0.8)),
                      material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10,fov=40,lookfrom=c(0,10,10))
```

```
#Elongate a pyramid:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_pyramid(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=2),z=2, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10,fov=40,lookfrom=c(0,10,10))

#Change the elongation point to start the elongation on the side of the pyramid:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_pyramid(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=-3,x=3),x=2.75,z=-2.75, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=2),z=2.25, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10,fov=40,
              lookfrom=c(5,5,10),lookat=c(0,0,-1.5))
```

`csg_group` *CSG Group*

Description

CSG Group

Usage

```
csg_group(object_list)
```

Arguments

`object_list`	List of objects created with the csg_* functions. This will make all further operations be applied to this object as a group.

Value

List describing the group in the scene.

Examples

```
#Group four spheres together and merge them with a box:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
  csg_group(list(csg_sphere(x=1,z=1, radius=0.5),csg_sphere(x=-1,z=1, radius=0.5),
                 csg_sphere(x=1,z=-1, radius=0.5),csg_sphere(x=-1,z=-1, radius=0.5))),
 csg_box(y=0.5, width=c(2,0.2,2)), operation="blend"), material=glossy(color="red"))) %>%
  add_object(sphere(y=10,x=-5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(5,5,10))
```

`csg_object` *Constructive Solid Geometry Object*

Description

This object takes an object constructed using the ‘csg_*‘ functions. The object is drawn using ray marching/sphere tracing.

Usage

```
csg_object(
  object,
  x = 0,
  y = 0,
  z = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`object`	Object created with CSG interface.
`x`	Default ‘0‘. x-offset of the center of the object.
`y`	Default ‘0‘. y-offset of the center of the object.
`z`	Default ‘0‘. z-offset of the center of the object.
`material`	Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Details

Note: For dielectric objects, any other objects not included in the CSG object and nested inside will be ignored.

Value

Single row of a tibble describing the sphere in the scene.

Examples

```
#We will combine these three objects:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_box(), material=glossy(color="red"))) %>%
  add_object(csg_object(csg_sphere(radius=0.707), material=glossy(color="green"))) %>%
 add_object(csg_object(csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                  csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                  csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
                  material=glossy(color="blue"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=15,lookfrom=c(5,5,10),
              samples=256, sample_method="sobol_blue")

#Standard CSG sphere + box - crossed cylinder combination:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_combine(
      csg_box(),
      csg_sphere(radius=0.707),
      operation="intersection"),
    csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                  csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                  csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
    operation="subtract"),
    material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=10,lookfrom=c(5,5,10),
              samples=256, sample_method="sobol_blue")

#Blend them all instead:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_combine(
      csg_box(),
      csg_sphere(radius=0.707),
      operation="blend"),
    csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                  csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                  csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
    operation="blend"),
    material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
   render_scene(clamp_value=10, fov=15,lookfrom=c(5,5,10),
                samples=256, sample_method="sobol_blue")
```

---

csg_onion *CSG Onion*

Description

Note: This operation has no overt effect on the external appearance of an object–it carves regions on the interior. Thus, you will only see an effect with a transparent material or when you carve into the object.

Usage

```
csg_onion(object, thickness = 0.1)
```

Arguments

`object`	CSG object.
`thickness`	Default '0.1'. Onioning distance.

Value

List describing the triangle in the scene.

Examples

```
#Cut and onion a sphere:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_onion(csg_sphere(z=2,x=2,radius=1), thickness = 0.2),
    csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
    material=glossy(color="red"))) %>%
    add_object(csg_object(csg_combine(
      csg_onion(csg_sphere(radius=1), thickness = 0.4),
      csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
      material=glossy(color="purple"))) %>%
    add_object(csg_object(csg_combine(
      csg_onion(csg_sphere(z=-2.5,x=-2.5,radius=1), thickness = 0.6),
      csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
      material=glossy(color="green"))) %>%
 add_object(sphere(y=5,x=5,radius=2,material=light())) %>%
 render_scene(clamp_value=10,lookat=c(0,-0.5,0),
              lookfrom=c(3,5,10),fov=35)

#Multiple onion layers:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_onion(csg_onion(csg_onion(csg_sphere(radius=1), 0.4), 0.2),0.1),
    csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
    material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,x=5,radius=2,material=light())) %>%
  render_scene(clamp_value=10,lookat=c(0,-0.5,0),
               lookfrom=c(3,5,10),fov=20)

#Onion with dielectric sphere to make a bubble:
generate_cornell() %>%
  add_object(csg_object(
    csg_onion(csg_sphere(x=555/2,y=555/2,z=555/2, radius=150), 5),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10)

#Multiple onion operations to make a bubble within a bubble:
generate_cornell() %>%
  add_object(csg_object(
    csg_onion(csg_onion(csg_sphere(x=555/2,y=555/2,z=555/2, radius=150), 10),5),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10)
```

csg_plane *CSG Plane*

Description

Note: This shape isn't closed, so there may be odd lighting issues if it's oriented the wrong way.

Usage

```
csg_plane(x = 0, y = 0, z = 0, normal = c(0, 1, 0), width_x = 4, width_z = 4)
```

Arguments

x	Default '0'. An x-coordinate on the plane.
y	Default '0'. A y-coordinate on the plane.
z	Default '0'. A z-coordinate on the plane.
normal	Default 'c(0,1,0)'. Surface normal of the plane.
width_x	Default '10'.
width_z	Default '10'.

Value

List describing the plane in the scene.

Examples

```
#Generate a plane
csg_object(csg_plane(width_x=4, width_z=4), material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10)

#Combine the plane with a sphere
csg_object(csg_combine(
    csg_sphere(radius=0.5),
    csg_plane(width_x=4, width_z=4,y=-0.5),
    operation="blend"),material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10)

#Re-orient the plane using the normal and
csg_object(csg_combine(
    csg_sphere(radius=0.5),
    csg_plane(normal = c(1,1,0),width_x=4, width_z=4,y=-0.5),
    operation="blend"),material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10)
```

`csg_pyramid` *CSG Pyramid*

Description

Note: This primitive slows down immensely for large values of base and height. Try using csg_scale() with this object for large pyramids instead.

Usage

```
csg_pyramid(x = 0, y = 0, z = 0, height = 1, base = 1)
```

Arguments

`x`	Default '0'. x-coordinate on the pyramid.
`y`	Default '0'. y-coordinate on the pyramid.
`z`	Default '0'. z-coordinate on the pyramid.
`height`	Default '1'. Pyramid height.
`base`	Default '1'. Pyramid base width.

Value

List describing the box in the scene.

Examples

```
#Generate a simple pyramid:
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))

#Make a taller pyramid
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.95, height=1.5),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))

#Make a wider pyramid
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.95, base=1.5),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))
```

---

csg_rotate *CSG Rotate*

Description

CSG Rotate

Usage

```
csg_rotate(
  object,
  pivot_point = c(0, 0, 0),
  angles = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  up = c(0, 1, 0),
  axis_x = NULL,
  axis_z = NULL
)
```

Arguments

object	CSG object.
pivot_point	Default ‘c(0,0,0)‘. Pivot point for the rotation.
angles	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
up	Default ‘c(0,1,0). Alternative method for specifying rotation–change the new "up" vector.
axis_x	Default ‘NULL‘, computed automatically if not passed. Given the ‘up‘ vector as the y-axis, this is the x vector.
axis_z	Default ‘NULL‘, computed automatically if not passed. Given the ‘up‘ vector as the y-axis, this is the z vector.

Value

List describing the triangle in the scene.

Examples

```
#Rotate a pyramid (translating it upwards because the object is scaled from the center):
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_rotate(csg_pyramid(z=-1.5,y=-0.99),
                        pivot_point = c(0,-0.99,-1.5),angle=c(0,45,0)),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=15,
               lookat=c(0,-0.5,0),clamp_value=10)

#Rotate by specifying a new up vector:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_rotate(csg_pyramid(z=-1.5,y=-0.49),
                        pivot_point = c(0,-0.49,-1.5), up =c(1,1,0)),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=15,
               lookat=c(0,-0.5,0),clamp_value=10)
```

`csg_round` *CSG Round*

Description

CSG Round

Usage

```
csg_round(object, radius = 0.1)
```

Arguments

`object`	CSG object.
`radius`	Default ‘0.1‘. Rounding distance.

Value

List describing the triangle in the scene.

Examples

```
#Generate a rounded pyramid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(x=-1,y=-0.99,z=1),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_round(csg_pyramid(x=1,y=-0.89)),
                        material=glossy(color="blue"))) %>%
  add_object(csg_object(csg_round(csg_pyramid(x=0,z=-2,y=-0.5), radius=0.5),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,radius=1,material=light(intensity=50))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=22,
               lookat=c(0,-0.5,0),clamp_value=10)

#Round a blend of two objects
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_round(csg_combine(
    csg_pyramid(x=-0.5,y=-0.99,z=1.5),
    csg_pyramid(x=0.5,y=-0.99,z=2), operation="blend"), radius=0),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_round(csg_combine(
    csg_pyramid(x=-0.5,y=-0.79,z=-1.5),
    csg_pyramid(x=0.5,y=-0.79,z=-1), operation="blend"), radius=0.2),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,radius=1,material=light(intensity=50))) %>%
  render_scene(lookfrom=c(-3,5,10), fov=22,
               lookat=c(0,-0.5,0),clamp_value=10)
```

csg_rounded_cone *CSG Rounded Cone*

Description

CSG Rounded Cone

Usage

```
csg_rounded_cone(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 0.5,
  upper_radius = 0.2
)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘0.5‘. Radius of the bottom of the cone.
upper_radius	Default ‘0.2‘. Radius from the top of the cone.

Value

List describing the box in the scene.

Examples

```
#Generate a basic rounded cone:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_rounded_cone(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10,fov=20)

#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_rounded_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))

#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_rounded_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
   csg_rounded_cone(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.2,upper_radius = 0.5)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))

#Render a glass rounded cone in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
   csg_rounded_cone(start = c(555/2,555/2-100,555/2), end = c(555/2,555/2+100,555/2), radius=100),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10)
```

`csg_scale` *CSG Scale*

Description

CSG Scale

Usage

```
csg_scale(object, scale = 1)
```

Arguments

`object`	CSG object.
`scale`	Default '1'.

Value

List describing the triangle in the scene.

Examples

```
#Scale a pyramid (translating it upwards because the object is scaled from the center):
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_scale(csg_pyramid(z=-1,y=-0.5),2),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=20,
               lookat=c(0,-0.5,-0.5),clamp_value=10)
```

csg_sphere *CSG Sphere*

Description

CSG Sphere

Usage

```
csg_sphere(x = 0, y = 0, z = 0, radius = 1)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the sphere.
y	Default ‘0‘. y-coordinate of the center of the sphere.
z	Default ‘0‘. z-coordinate of the center of the sphere.
radius	Default ‘1‘. Radius of the sphere.

Value

List describing the sphere in the scene.

Examples

```
#Generate a simple sphere:
generate_ground() %>%
  add_object(csg_object(csg_sphere(),
                        material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10)

#Generate a bigger sphere in the cornell box.
generate_cornell() %>%
  add_object(csg_object(csg_sphere(x=555/2,y=555/2,z=555/2,radius=100),
                        material=glossy(checkercolor="purple", checkerperiod=100))) %>%
  render_scene(clamp_value=10)

#Combine two spheres of different sizes
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2,y=555/2+50,z=555/2,radius=80)),
    material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10)

#Subtract two spheres to create an indented region
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2+30,y=555/2+20,z=555/2-90,radius=40),
      operation="subtract"),
    material=glossy(color="grey20"))) %>%
  render_scene(clamp_value=10)

#Use csg_combine(operation="blend") to melt the two together
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2,y=555/2+50,z=555/2,radius=80),
      operation="blend", radius=20),
    material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10)
```

csg_torus *CSG Torus*

Description

CSG Torus

Usage

```
csg_torus(x = 0, y = 0, z = 0, radius = 1, minor_radius = 0.5)
```

Arguments

x	Default ‘0‘. x-coordinate on the torus.
y	Default ‘0‘. y-coordinate on the torus.
z	Default ‘0‘. z-coordinate on the torus.
radius	Default ‘1‘. Torus radius.
minor_radius	Default ‘0.5‘. Cross section radius of the torus.

Value

List describing the torus in the scene.

Examples

```
#Generate a torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(), material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(0,5,10),fov=30)

#Change the radius of the torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(radius=2), material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(0,5,10),fov=30)

#Change the minor radius of the torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(radius=2, minor_radius=0.25),
                      material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(0,5,10),fov=30)

#Generate a rotated torus in the Cornell Box
generate_cornell() %>%
  add_object(csg_object(csg_rotate(
    csg_torus(x=555/2,y=555/2,z=555/2,radius=100, minor_radius=50),
    pivot_point = c(555/2,555/2,555/2), up =c(0,1,-1)),
                      material=glossy(color="dodgerblue4"))) %>%
  render_scene(clamp_value=10)
```

`csg_translate` *CSG Translate*

Description

CSG Translate

Usage

```
csg_translate(object, x = 0, y = 0, z = 0)
```

Arguments

object	CSG object.
x	Default ‘0‘. x translation.
y	Default ‘0‘. y translation.
z	Default ‘0‘. z translation.

Value

List describing the triangle in the scene.

Examples

```
#Translate a simple object:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(), material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(csg_torus(),x=-2,y=1,z=-2),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(0,5,10),fov=30,
               lookat=c(-1,0.5,-1))

#Translate a blended object:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_torus(),
   csg_torus(y=1, radius=0.8), operation="blend"), material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(
    csg_combine(
      csg_torus(),
      csg_torus(y=1, radius=0.8), operation="blend"),
    x=-3,y=1,z=-3),
    material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10,lookfrom=c(0,5,10),fov=30,
               lookat=c(-1.5,0.5,-1.5))
```

---

csg_triangle *CSG Triangle*

Description

CSG Triangle

Usage

```
csg_triangle(v1 = c(0, 1, 0), v2 = c(1, 0, 0), v3 = c(-1, 0, 0))
```

Arguments

v1	Default ‘c(0,1,0)‘. First vertex.
v2	Default ‘c(1,0,0)‘. Second vertex.
v3	Default ‘c(-1,0,0)‘. Third vertex.

Value

List describing the triangle in the scene.

Examples

```
#Generate a basic triangle:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_triangle(),material=diffuse(color="red"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10,fov=20)

#Change a vertex:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_triangle(v1 = c(1,1,0)),material=diffuse(color="green"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10,fov=20)

#Change all three vertices:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_triangle(v1 = c(0.5,1,0), v2 = c(1,-0.5,0), v3 = c(-1,0.5,0)),
                       material=diffuse(color="blue"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10,fov=20,lookfrom=c(0,5,10))
```

---

cube *Cube Object*

Description

Cube Object

Usage

```
cube(
  x = 0,
  y = 0,
  z = 0,
  width = 1,
  xwidth = 1,
  ywidth = 1,
  zwidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the cube
`y`	Default ‘0‘. y-coordinate of the center of the cube
`z`	Default ‘0‘. z-coordinate of the center of the cube
`width`	Default ‘1‘. Cube width.
`xwidth`	Default ‘1‘. x-width of the cube. Overrides ‘width‘ argument for x-axis.
`ywidth`	Default ‘1‘. y-width of the cube. Overrides ‘width‘ argument for y-axis.
`zwidth`	Default ‘1‘. z-width of the cube. Overrides ‘width‘ argument for z-axis.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
#Generate a cube in the cornell box.

generate_cornell() %>%
  add_object(cube(x = 555/2, y = 100, z = 555/2,
                  xwidth = 200, ywidth = 200, zwidth = 200, angle = c(0, 30, 0))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)

#Generate a gold cube in the cornell box

generate_cornell() %>%
  add_object(cube(x = 555/2, y = 100, z = 555/2,
                  xwidth = 200, ywidth = 200, zwidth = 200, angle = c(0, 30, 0),
                  material = metal(color = "gold", fuzz = 0.2))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)


#Generate a rotated dielectric box in the cornell box

generate_cornell() %>%
  add_object(cube(x = 555/2, y = 200, z = 555/2,
                  xwidth = 200, ywidth = 100, zwidth = 200, angle = c(-30, 30, -30),
                  material = dielectric())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)
```

---

cylinder *Cylinder Object*

Description

Cylinder Object

Usage

```
cylinder(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  length = 1,
  phi_min = 0,
  phi_max = 360,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1),
  capped = TRUE
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the cylinder
`y`	Default ‘0‘. y-coordinate of the center of the cylinder
`z`	Default ‘0‘. z-coordinate of the center of the cylinder
`radius`	Default ‘1‘. Radius of the cylinder.
`length`	Default ‘1‘. Length of the cylinder.
`phi_min`	Default ‘0‘. Minimum angle around the segment.
`phi_max`	Default ‘360‘. Maximum angle around the segment.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly.
`capped`	Default ‘TRUE‘. Whether to add caps to the segment. Turned off when using the ‘light()‘ material. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cylinder in the scene.

Examples

```
#Generate a cylinder in the cornell box. Add a cap to both ends.


generate_cornell() %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2,
                      length = 300, radius = 100, material = metal())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)

#Rotate the cylinder

generate_cornell() %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2,
                      length = 300, radius = 100, angle = c(0, 0, 45),
                      material = diffuse())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)


# Only render a subtended arc of the cylinder,

generate_cornell(lightintensity=3) %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2, capped = FALSE,
                length = 300, radius = 100, angle = c(45, 0, 0), phi_min = 0, phi_max = 180,
                      material = diffuse())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

`dielectric` *Dielectric (glass) Material*

Description

Dielectric (glass) Material

Usage

```
dielectric(
  color = "white",
  refraction = 1.5,
  attenuation = c(0, 0, 0),
  priority = 0,
  importance_sample = FALSE,
  bump_texture = NA,
  bump_intensity = 1
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`refraction`	Default ‘1.5‘. The index of refraction.
`attenuation`	Default ‘c(0,0,0)‘. The Beer-Lambert color-channel specific exponential attenuation through the material. Higher numbers will result in less of that color making it through the material. Note: This assumes the object has a closed surface.
`priority`	Default ‘0‘. When two dielectric materials overlap, the one with the lower priority value is used for intersection. NOTE: If the camera is placed inside a dielectric object, its priority value will not be taken into account when determining hits to other objects also inside the object.
`importance_sample`	Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.
`bump_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
`bump_intensity`	Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.

Value

Single row of a tibble describing the dielectric material.

Examples

```
#Generate a checkered ground
scene = generate_ground(depth=-0.5, material = diffuse(checkercolor="grey30",checkerperiod=2))
```

```
render_scene(scene,parallel=TRUE)


#Add a glass sphere

scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
  render_scene(parallel=TRUE,samples=400)


#Add a rotated colored glass cube

scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
 add_object(cube(x=0.5,xwidth=0.5,material=dielectric(color="darkgreen"),angle=c(0,-45,0))) %>%
  render_scene(parallel=TRUE,samples=400)


#Add an area light behind and at an angle and turn off the ambient lighting

scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
 add_object(cube(x=0.5,xwidth=0.5,material=dielectric(color="darkgreen"),angle=c(0,-45,0))) %>%
  add_object(yz_rect(z=-3,y=1,x=0,zwidth=3,ywidth=1.5,
                     material=light(intensity=15),
                     angle=c(0,-90,45), order_rotation = c(3,2,1))) %>%
  render_scene(parallel=TRUE,aperture=0, ambient_light=FALSE,samples=1000)


#Color glass using Beer-Lambert attenuation, which attenuates light on a per-channel
#basis as it travels through the material. This effect is what gives some types of glass
#a green glow at the edges. We will get this effect by setting a lower attenuation value
#for the `green` (second) channel in the dielectric `attenuation` argument.

generate_ground(depth=-0.5,material=diffuse(checkercolor="grey30",checkerperiod=2)) %>%
  add_object(sphere(z=-5,x=-0.5,y=1,material=light(intensity=10))) %>%
  add_object(cube(y=0.3,ywidth=0.1,xwidth=2,zwidth=2,
                 material=dielectric(attenuation=c(1.2,0.2,1.2)),angle=c(45,110,0))) %>%
  render_scene(parallel=TRUE, samples = 1000)


#If you have overlapping dielectrics, the `priority` value can help disambiguate what
#object wins. Here, I place a bubble inside a cube by setting a lower priority value and
#making the inner sphere have a index of refraction of 1. I also place spheres at the corners.

generate_ground(depth=-0.51,material=diffuse(checkercolor="grey30",checkerperiod=2)) %>%
  add_object(cube(material = dielectric(priority=2, attenuation = c(10,3,10)))) %>%
  add_object(sphere(radius=0.49,material = dielectric(priority=1, refraction=1))) %>%
  add_object(sphere(radius=0.25,x=0.5,z=-0.5,y=0.5,
                    material = dielectric(priority=0,attenuation = c(10,3,10) ))) %>%
  add_object(sphere(radius=0.25,x=-0.5,z=0.5,y=0.5,
                    material = dielectric(priority=0,attenuation = c(10,3,10)))) %>%
  render_scene(parallel=TRUE, samples = 400,lookfrom=c(5,1,5))


# We can also use this as a basic Constructive Solid Geometry interface by setting
# the index of refraction equal to empty space, 1. This will subtract out those regions.
# Here I make a concave lens by subtracting two spheres from a cube.

generate_ground(depth=-0.51,material=diffuse(checkercolor="grey30",checkerperiod=2,sigma=90)) %>%
  add_object(cube(material = dielectric(attenuation = c(3,3,1),priority=1))) %>%
  add_object(sphere(radius=1,x=1.01,
                    material = dielectric(priority=0,refraction=1))) %>%
  add_object(sphere(radius=1,x=-1.01,
                    material = dielectric(priority=0,refraction=1))) %>%
  add_object(sphere(y=10,x=3,material=light(intensit=150))) %>%
  render_scene(parallel=TRUE, samples = 400,lookfrom=c(5,3,5))
```

diffuse *Diffuse Material*

Description

Diffuse Material

Usage

```
diffuse(
  color = "#ffffff",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = NA,
  image_repeat = 1,
  alpha_texture = NA,
  bump_texture = NA,
  bump_intensity = 1,
  fog = FALSE,
  fogdensity = 0.01,
  sigma = NULL,
  importance_sample = FALSE
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkercolor`	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkerperiod`	Default ‘3‘. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
`noise`	Default ‘0‘. If not ‘0‘, covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
`noisephase`	Default ‘0‘. The phase of the noise. The noise will repeat at ‘360‘.
`noiseintensity`	Default ‘10‘. Intensity of the noise.
`noisecolor`	Default ‘#000000‘. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`gradient_color`	Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.
`gradient_transpose`	Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.
`gradient_point_start`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.
`gradient_point_end`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.
`gradient_type`	Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.
`image_texture`	Default ‘NA‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
`image_repeat`	Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.
`alpha_texture`	Default ‘NA‘. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.
`bump_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
`bump_intensity`	Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.
`fog`	Default ‘FALSE‘. If ‘TRUE‘, the object will be a volumetric scatterer.

`fogdensity`	Default ‘0.01‘. The density of the fog. Higher values will produce more opaque objects.
`sigma`	Default ‘NULL‘. A number between 0 and Infinity specifying the roughness of the surface using the Oren-Nayar microfacet model. Higher numbers indicate a roughed surface, where sigma is the standard deviation of the microfacet orientation angle. When 0, this reverts to the default lambertian behavior.
`importance_sample`	Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the diffuse material.

Examples

```
#Generate the cornell box and add a single white sphere to the center
scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=diffuse()))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Add a checkered rectangular cube below
scene = scene %>%
  add_object(cube(x=555/2,y=555/8,z=555/2,xwidth=555/2,ywidth=555/4,zwidth=555/2,
  material = diffuse(checkercolor="purple",checkerperiod=20)))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Add a marbled sphere
scene = scene %>%
  add_object(sphere(x=555/2+555/4,y=555/2,z=555/2,radius=555/8,
  material = diffuse(noise=1/20)))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Add an orange volumetric (fog) cube
scene = scene %>%
  add_object(cube(x=555/2-555/4,y=555/2,z=555/2,xwidth=555/4,ywidth=555/4,zwidth=555/4,
  material = diffuse(fog=TRUE, fogdensity=0.05,color="orange")))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#' #Add an line segment with a color gradient
scene = scene %>%
  add_object(segment(start = c(555,450,450),end=c(0,450,450),radius = 50,
                     material = diffuse(color="#1f7326", gradient_color = "#a60d0d")))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
```

`disk` *Disk Object*

Description

Disk Object

Usage

```
disk(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  inner_radius = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the disk
`y`	Default ‘0‘. y-coordinate of the center of the disk
`z`	Default ‘0‘. z-coordinate of the center of the disk
`radius`	Default ‘1‘. Radius of the disk.
`inner_radius`	Default ‘0‘. Inner radius of the disk.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the disk in the scene.

Examples

```
#Generate a disk in the cornell box.

generate_cornell() %>%
  add_object(disk(x = 555/2, y = 50, z = 555/2, radius = 150,
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)

#Rotate the disk.

generate_cornell() %>%
  add_object(disk(x = 555/2, y = 555/2, z = 555/2, radius = 150, angle = c(-45, 0, 0),
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) , lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)

#Pass a value for the inner radius.

generate_cornell() %>%
  add_object(disk(x = 555/2, y = 555/2, z = 555/2,
                  radius = 150, inner_radius = 75, angle = c(-45, 0, 0),
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

`ellipsoid` *Ellipsoid Object*

Description

Note: light importance sampling for this shape is currently approximated by a sphere. This will fail for ellipsoids with large differences between axes.

Usage

```
ellipsoid(
  x = 0,
  y = 0,
  z = 0,
  a = 1,
  b = 1,
  c = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the ellipsoid.
`y`	Default ‘0‘. y-coordinate of the center of the ellipsoid.
`z`	Default ‘0‘. z-coordinate of the center of the ellipsoid.
`a`	Default ‘1‘. Principal x-axis of the ellipsoid.
`b`	Default ‘1‘. Principal y-axis of the ellipsoid.
`c`	Default ‘1‘. Principal z-axis of the ellipsoid.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the ellipsoid in the scene.

Examples

```
#Generate an ellipsoid in a Cornell box

generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 50, c = 50)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
              ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)


#Change the axes to make it taller rather than wide:

generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 200, c = 100, material = metal())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
              ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)


#Rotate it and make it dielectric:

generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 200, c = 100, angle = c(0, 0, 45),
                       material = dielectric())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
              ambient_light = FALSE, samples = 500, parallel = TRUE, clamp_value = 5)
```

extruded_polygon *Extruded Polygon Object*

Description

Extruded Polygon Object

Usage

```
extruded_polygon(
  polygon = NULL,
  x = 0,
  y = 0,
  z = 0,
  plane = "xz",
  top = 1,
  bottom = 0,
  holes = NULL,
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  pivot_point = c(0, 0, 0),
  material = diffuse(),
  center = FALSE,
  flip_horizontal = FALSE,
  flip_vertical = FALSE,
  data_column_top = NULL,
  data_column_bottom = NULL,
  scale_data = 1,
  scale = c(1, 1, 1),
  material_id = NA
)
```

Arguments

`polygon`	‘sf‘ object, "SpatialPolygon" ‘sp‘ object, or xy coordinates of polygon represented in a way that can be processed by ‘xy.coords()‘. If xy-coordinate based polygons are open, they will be closed by adding an edge from the last point to the first.
`x`	Default ‘0‘. x-coordinate to offset the extruded model.
`y`	Default ‘0‘. y-coordinate to offset the extruded model.
`z`	Default ‘0‘. z-coordinate to offset the extruded model.
`plane`	Default ‘xz‘. The plane the polygon is drawn in. All possibile orientations are ‘xz‘, ‘zx‘, ‘xy‘, ‘yx‘, ‘yz‘, and ‘zy‘.
`top`	Default ‘1‘. Extruded top distance. If this equals ‘bottom‘, the polygon will not be extruded and just the one side will be rendered.
`bottom`	Default ‘0‘. Extruded bottom distance. If this equals ‘top‘, the polygon will not be extruded and just the one side will be rendered.
`holes`	Default ‘0‘. If passing in a polygon directly, this specifies which index represents the holes in the polygon. See the ‘earcut‘ function in the ‘decido‘ package for more information.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`pivot_point`	Default ‘c(0,0,0)‘. Point at which to rotate the polygon around.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`center`	Default ‘FALSE‘. Whether to center the polygon at the origin.
`flip_horizontal`	Default ‘FALSE‘. Flip polygon horizontally in the plane defined by ‘plane‘.
`flip_vertical`	Default ‘FALSE‘. Flip polygon vertically in the plane defined by ‘plane‘.
`data_column_top`	Default ‘NULL‘. A string indicating the column in the ‘sf‘ object to use to specify the top of the extruded polygon.
`data_column_bottom`	Default ‘NULL‘. A string indicating the column in the ‘sf‘ object to use to specify the bottom of the extruded polygon.
`scale_data`	Default ‘1‘. If specifying ‘data_column_top‘ or ‘data_column_bottom‘, how much to scale that value when rendering.

scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.
material_id	Default ‘NA‘. A unique label/number to ensure the material is shared between all triangles that make up the extruded polygon. Required if the material is ‘dielectric()‘.

Value

Multiple row tibble describing the extruded polygon in the scene.

Examples

```
#Manually create a polygon object, here a star:

angles = seq(0,360,by=36)
xx = rev(c(rep(c(1,0.5),5),1) * sinpi(angles/180))
yy = rev(c(rep(c(1,0.5),5),1) * cospi(angles/180))
star_polygon = data.frame(x=xx,y=yy)


generate_ground(depth=0,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(star_polygon,top=0.5,bottom=0,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,z=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,3),samples=400,lookat=c(0,0.5,0),fov=60)


#Now, let's add a hole to the center of the polygon. We'll make the polygon
#hollow by shrinking it, combining it with the normal size polygon,
#and specify with the `holes` argument that everything after `nrow(star_polygon)`
#in the following should be used to draw a hole:

hollow_star = rbind(star_polygon,0.8*star_polygon)


generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
 add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon) + 1,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,z=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,4),samples=400,lookat=c(0,0,0),fov=30)


# Render one in the y-x plane as well by changing the `plane` argument,
# as well as offset it slightly.

generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon),
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, z=-1.2,
                              holes = nrow(star_polygon) + 1, plane = "yx",
                              material=diffuse(color="green",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,4),samples=400,lookat=c(0,0.9,0),fov=40)


# Now add the zy plane:

generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
 add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon) + 1,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, z=-1.2,
                              holes = nrow(star_polygon) + 1, plane = "yx",
                              material=diffuse(color="green",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, x=1.2,
                              holes = nrow(star_polygon) + 1, plane = "zy",
                              material=diffuse(color="blue",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(-4,2,4),samples=400,lookat=c(0,0.9,0),fov=40)


#We can also directly pass in sf polygons:
if(length(find.package("spData",quiet=TRUE)) > 0) {
  us_states = spData::us_states
  texas = us_states[us_states$NAME == "Texas",]
  #Fix no sfc class in us_states geometry data
  class(texas$geometry) = c("list","sfc")
}

#This uses the raw coordinates, unless `center = TRUE`, which centers the bounding box
#of the polygon at the origin.

generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(texas, center = TRUE,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-30,radius=10,
                    material=light(color="lightblue",intensity=40))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,10,-10),samples=400,fov=60)


#Here we use the raw coordinates, but offset the polygon manually.

generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(us_states, x=-96,z=-40, top=2,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-100,radius=10,
                    material=light(color="lightblue",intensity=200))) %>%
  add_object(sphere(y=30,x=100,radius=10,
                    material=light(color="orange",intensity=200))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,120,-120),samples=400,fov=20)


#We can also set the map the height of each polygon to a column in the sf object,
#scaling it down by the maximum population state.


generate_ground(depth=0,
                material = diffuse(color="grey50",checkercolor="grey20",sigma=90)) %>%
  add_object(extruded_polygon(us_states, x=-96,z=-45, data_column_top = "total_pop_15",
                              scale_data = 1/max(us_states$total_pop_15)*5,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-100,z=60,radius=10,
                    material=light(color="lightblue",intensity=250))) %>%
  add_object(sphere(y=30,x=100,z=-60,radius=10,
                    material=light(color="orange",intensity=250))) %>%
 render_scene(parallel=TRUE,lookfrom = c(-60,50,-40),lookat=c(0,-5,0),samples=400,fov=30)
```

`generate_camera_motion` *Generate Camera Movement*

Description

Takes a series of key frame camera positions and smoothly interpolates between them. Generates a data.frame that can be passed to ‘render_animation()‘.

Usage

```
generate_camera_motion(
  positions,
  lookats = NULL,
  apertures = 0,
  fovs = 40,
  focal_distances = NULL,
  ortho_dims = NULL,
  camera_ups = NULL,
  type = "bezier",
  frames = 30,
  closed = FALSE,
  aperture_linear = TRUE,
  fov_linear = TRUE,
  focal_linear = TRUE,
  ortho_linear = TRUE,
  constant_step = TRUE,
  curvature_adjust = "none",
  curvature_scale = 30,
  offset_lookat = 0,
  progress = TRUE
)
```

Arguments

positions	A list or 3-column XYZ matrix of camera positions. These will serve as key frames for the camera position.
lookats	Default ‘NULL‘, which sets the camera lookat to the origin ‘c(0,0,0)‘ for the animation. A list or 3-column XYZ matrix of ‘lookat‘ points. Must be the same number of points as ‘positions‘.
apertures	Default ‘0‘. A numeric vector of aperture values.
fovs	Default ‘40‘. A numeric vector of field of view values.
focal_distances	Default ‘NULL‘, automatically the distance between positions and lookats. Numeric vector of focal distances.
ortho_dims	Default ‘NULL‘, which results in ‘c(1,1)‘ orthographic dimensions. A list or 2-column matrix of orthographic dimensions.
camera_ups	Default ‘NULL‘, which gives at up vector of ‘c(0,1,0)‘. Camera up orientation.
type	Default ‘bezier‘. Type of transition between keyframes. Other options are ‘linear‘, ‘quad‘, ‘cubic‘, ‘exp‘, and ‘manual‘. ‘manual‘ just returns the values passed in, properly formatted to be passed to ‘render_animation()‘.
frames	Default ‘30‘. Total number of frames.
closed	Default ‘FALSE‘. Whether to close the camera curve so the first position matches the last. Set this to ‘TRUE‘ for perfect loops.
aperture_linear	Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.
fov_linear	Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.
focal_linear	Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.
ortho_linear	Default ‘TRUE‘. This linearly interpolates orthographic dimensions, rather than using a smooth Bezier curve or easing function.
constant_step	Default ‘TRUE‘. This will make the camera travel at a constant speed.
curvature_adjust	Default ‘none‘. Other options are ‘position‘, ‘lookat‘, and ‘both‘. Whether to slow down the camera at areas of high curvature to prevent fast swings. Only used for curve ‘type = bezier‘. This does not preserve key frame positions. Note: This feature will likely result in the ‘lookat‘ and ‘position‘ diverging if they do not have similar curvatures at each point. This feature is best used when passing the same set of points to ‘positions‘ and ‘lookats‘ and providing an ‘offset_lookat‘ value, which ensures the curvature will be the same.

`curvature_scale`	Default '30'. Constant dividing factor for curvature. Higher values will subdivide the path more, potentially finding a smoother path, but increasing the calculation time. Only used for curve 'type = bezier'. Increasing this value after a certain point will not increase the quality of the path, but it is scene-dependent.
`offset_lookat`	Default '0'. Amount to offset the lookat position, either along the path (if 'constant_step = TRUE') or towards the derivative of the Bezier curve.
`progress`	Default 'TRUE'. Whether to display a progress bar.

Value

Data frame of camera positions, orientations, apertures, focal distances, and field of views

Examples

```
#Create and animate flying through a scene on a simulated roller coaster

set.seed(3)
elliplist = list()
ellip_colors = rainbow(8)
for(i in 1:1200) {
  elliplist[[i]] = ellipsoid(x=10*runif(1)-5,y=10*runif(1)-5,z=10*runif(1)-5,
                             angle = 360*runif(3), a=0.1,b=0.05,c=0.1,
                             material=glossy(color=sample(ellip_colors,1)))
}
ellip_scene = do.call(rbind, elliplist)

camera_pos = list(c(0,1,15),c(5,-5,5),c(-5,5,-5),c(0,1,-15))

#Plot the camera path and render from above using the path object:
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,20,0), width=800,height=800,samples=32,
               camera_up = c(0,0,1),
               fov=80)

#Side view
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(20,0,0),width=800,height=800,samples=32,
                fov=80)

#View from the start
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,1.5,16),width=800,height=800,samples=32,
                 fov=80)

#Generate Camera movement, setting the lookat position to be same as camera position, but offset
#slightly in front. We'll render 12 frames, but you'd likely want more in a real animation.

camera_motion =  generate_camera_motion(positions = camera_pos, lookats = camera_pos,
                                       offset_lookat = 1, fovs=80, frames=12)

#This returns a data frame of individual camera positions, interpolated by cubic bezier curves.
camera_motion

#Pass NA filename to plot to the device. We'll keep the path and offset it slightly to see
#where we're going. This results in a "roller coaster" effect.
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(obj_model(r_obj(),x=10,y=-10,scale_obj=3, angle=c(0,-45,0),
                      material=dielectric(attenuation=c(1,1,0.3)))) %>%
  add_object(pig(x=-7,y=10,z=-5,scale=1,angle=c(0,-45,80),emotion="angry")) %>%
  add_object(pig(x=0,y=-0.25,z=-15,scale=1,angle=c(0,225,-20),
                 emotion="angry", spider=TRUE)) %>%
  add_object(path(camera_pos, y=-0.2,material=diffuse(color="red"))) %>%
  render_animation(filename = NA, camera_motion = camera_motion, samples=100,
                   sample_method="sobol_blue",
                   clamp_value=10, width=400, height=400)
```

generate_cornell *Generate Cornell Box*

Description

Generate Cornell Box

Usage

```
generate_cornell(
  light = TRUE,
  lightintensity = 5,
  lightcolor = "white",
  lightwidth = 332,
  lightdepth = 343,
  sigma = 0,
  leftcolor = "#1f7326",
  rightcolor = "#a60d0d",
  roomcolor = "#bababa",
  importance_sample = TRUE
)
```

Arguments

`light`	Default ‘TRUE‘. Whether to include a light on the ceiling of the box.
`lightintensity`	Default ‘5‘. The intensity of the light.
`lightcolor`	Default ‘white‘. The color the of the light.
`lightwidth`	Default ‘332‘. Width (z) of the light.
`lightdepth`	Default ‘343‘. Depth (x) of the light.
`sigma`	Default ‘0‘. Oren-Nayar microfacet angle.
`leftcolor`	Default ‘#1f7326‘ (green).
`rightcolor`	Default ‘#a60d0d‘ (red).
`roomcolor`	Default ‘#bababa‘ (light grey).
`importance_sample`	Default ‘TRUE‘. Importance sample the light in the room.

Value

Tibble containing the scene description of the Cornell box.

Examples

```
#Generate and render the default Cornell box.
scene = generate_cornell()

render_scene(scene, samples=400,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Make a much smaller light in the center of the room.
scene = generate_cornell(lightwidth=200,lightdepth=200)

render_scene(scene, samples=400,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Place a sphere in the middle of the box.
scene = scene %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/4))

render_scene(scene, samples=400,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Reduce "fireflies" by setting a clamp_value in render_scene()

render_scene(scene, samples=400,aperture=0, fov=40, ambient_light=FALSE,
             parallel=TRUE,clamp_value=3)

# Change the color scheme of the cornell box

new_cornell = generate_cornell(leftcolor="purple", rightcolor="yellow")
render_scene(new_cornell, samples=400,aperture=0, fov=40, ambient_light=FALSE,
             parallel=TRUE,clamp_value=3)
```

generate_ground *Generate Ground*

Description

Generates a large sphere that can be used as the ground for a scene.

Usage

```
generate_ground(
  depth = -1,
  spheresize = 1000,
  material = diffuse(color = "#ccff00")
)
```

Arguments

depth	Default '-1'. Depth of the surface.
spheresize	Default '1000'. Radius of the sphere representing the surface.
material	Default diffuse with 'color= "#ccff00"'.The material, called from one of the material functions diffuse, metal, or dielectric.
color	Default '#ccff00'. The color of the sphere. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

Value

Single row of a tibble describing the ground.

Examples

```
#Generate the ground and add some objects
scene = generate_ground(depth=-0.5,
                        material = diffuse(noise=1,noisecolor="blue",noisephase=10)) %>%
  add_object(cube(x=0.7,material=diffuse(color="red"),angle=c(0,-15,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=dielectric(color="white")))

render_scene(scene, parallel=TRUE,lookfrom=c(0,2,10))


# Make the sphere representing the ground larger and make it a checkered surface.
scene = generate_ground(depth=-0.5, spheresize=10000,
                        material = diffuse(checkercolor="grey50")) %>%
  add_object(cube(x=0.7,material=diffuse(color="red"),angle=c(0,-15,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=dielectric(color="white")))

render_scene(scene, parallel=TRUE,lookfrom=c(0,1,10))
```

`generate_studio` *Generate Studio*

Description

Generates a curved studio backdrop.

Usage

```
generate_studio(
  depth = -1,
  distance = -10,
  width = 100,
  height = 100,
  curvature = 8,
  material = diffuse()
)
```

Arguments

`depth`	Default '-1'. Depth of the ground in the scene.
`distance`	Default '-10'. Distance to the backdrop in the scene from the origin, on the z-axis.
`width`	Default '100'. Width of the backdrop.
`height`	Default '100'. height of the backdrop.
`curvature`	Default '2'. Radius of the curvature connecting the bottom plane to the vertical backdrop.
`material`	Default `diffuse` with 'color= "#ccff00"'.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.

Value

Tibble representing the scene.

Examples

```
#Generate the ground and add some objects
scene = generate_studio(depth=-1, material = diffuse(color="white")) %>%
 add_object(obj_model(r_obj(),y=-1,x=0.7,material=glossy(color="darkred"),angle=c(0,-20,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=dielectric())) %>%
  add_object(sphere(y=3,x=-2,z=20,material=light(intensity=600)))

render_scene(scene, parallel=TRUE,lookfrom=c(0,2,10),fov=20,clamp_value=10,samples=500)


#Zooming out to show the full default scene
```

```
render_scene(scene, parallel=TRUE,lookfrom=c(0,200,400),clamp_value=10,samples=500)
```

---

glossy *Glossy Material*

Description

Glossy Material

Usage

```
glossy(
  color = "white",
  gloss = 1,
  reflectance = 0.05,
  microfacet = "tbr",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = NA,
  image_repeat = 1,
  alpha_texture = NA,
  bump_texture = NA,
  roughness_texture = NA,
  bump_intensity = 1,
  roughness_range = c(1e-04, 0.2),
  roughness_flip = FALSE,
  importance_sample = FALSE
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`gloss`	Default ‘0.8‘. Gloss of the surface, between ‘1‘ (completely glossy) and ‘0‘ (rough glossy). Can be either a single number, or two numbers indicating an anisotropic distribution of normals (as in ‘microfacet()‘).

`reflectance`	Default ‘0.03‘. The reflectivity of the surface. ‘1‘ is a full mirror, ‘0‘ is diffuse with a glossy highlight.
`microfacet`	Default ‘tbr‘. Type of microfacet distribution. Alternative option ‘beckmann‘.
`checkercolor`	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkerperiod`	Default ‘3‘. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
`noise`	Default ‘0‘. If not ‘0‘, covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
`noisephase`	Default ‘0‘. The phase of the noise. The noise will repeat at ‘360‘.
`noiseintensity`	Default ‘10‘. Intensity of the noise.
`noisecolor`	Default ‘#000000‘. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`gradient_color`	Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.
`gradient_transpose`	Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.
`gradient_point_start`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.
`gradient_point_end`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.
`gradient_type`	Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.
`image_texture`	Default ‘NA‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
`image_repeat`	Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.
`alpha_texture`	Default ‘NA‘. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.
`bump_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
`roughness_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a roughness map for the surface.

`bump_intensity`	Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.
`roughness_range`	Default ‘ c(0.0001, 0.2)‘. This is a length-2 vector that specifies the range of roughness values that the ‘roughness_texture‘ can take.
`roughness_flip`	Default ‘FALSE‘. Setting this to ‘TRUE‘ flips the roughness values specified in the ‘roughness_texture‘ so high values are now low values and vice versa.
`importance_sample`	Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the glossy material.

Examples

```
#Generate a glossy sphere
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff"))) %>%
  add_object(sphere(y=2.8,material=light())) %>%
  render_scene(parallel=TRUE,clamp_value=10,samples=256,sample_method="sobol_blue")

#Change the color of the underlying diffuse layer
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(color="#fc3d03"))) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff"))) %>%
  add_object(sphere(y=0.2,x=2.1,material=glossy(color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=256,fov=40,sample_method="sobol_blue")

#Change the amount of gloss
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(gloss=1,color="#fc3d03"))) %>%
  add_object(sphere(y=0.2,material=glossy(gloss=0.5,color="#2b6eff"))) %>%
  add_object(sphere(y=0.2,x=2.1,material=glossy(gloss=0,color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=256,fov=40,sample_method="sobol_blue")

#Add gloss to a pattern
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(noise=2,noisecolor="black"))) %>%
  add_object(sphere(y=0.2,material=glossy(color="#ff365a",checkercolor="#2b6eff"))) %>%
 add_object(sphere(y=0.2,x=2.1,material=glossy(color="blue",gradient_color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=256,fov=40,sample_method="sobol_blue")
```

```
#Add an R and a fill light (this may look familiar)
generate_ground(material=diffuse()) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff",reflectance=0.05))) %>%
  add_object(obj_model(r_obj(),z=1,y=-0.05,scale_obj=0.45,material=diffuse())) %>%
  add_object(sphere(y=6,z=1,radius=4,material=light(intensity=3))) %>%
  add_object(sphere(z=15,material=light(intensity=50))) %>%
  render_scene(parallel=TRUE,clamp_value=10,samples=256,sample_method="sobol_blue")
```

group_objects *Group Objects*

Description

Group and transform objects together.

Usage

```
group_objects(
  scene,
  pivot_point = c(0, 0, 0),
  translate = c(0, 0, 0),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  scale = c(1, 1, 1),
  axis_rotation = NA
)
```

Arguments

scene	Tibble of pre-existing object locations and properties to group together.
pivot_point	Default ‘c(0,0,0)‘. The point about which to pivot, scale, and move the group.
translate	Default ‘c(0,0,0)‘. Vector indicating where to offset the group.
angle	Default ‘c(0,0,0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1,2,3)‘. The order to apply the rotations, referring to "x", "y", and "z".
scale	Default ‘c(1,1,1)‘. Scaling factor for x, y, and z directions for all objects in group.
axis_rotation	Default ‘NA‘. Provide an axis of rotation and a single angle (via ‘angle‘) of rotation around that axis.

Value

Tibble of grouped object locations and properties.

Examples

```
#Generate the ground and add some objects
scene = generate_cornell() %>%
        add_object(cube(x=555/2,y=555/8,z=555/2,width=555/4)) %>%
        add_object(cube(x=555/2,y=555/4+555/16,z=555/2,width=555/8))

render_scene(scene,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=500, fov=50, parallel=TRUE, clamp_value=5)


#Group the entire room and rotate around its center, but keep the cubes in the same place.
scene2 = group_objects(generate_cornell(),
                       pivot_point=c(555/2,555/2,555/2),
                       angle=c(0,30,0)) %>%
         add_object(cube(x=555/2,y=555/8,z=555/2,width=555/4)) %>%
        add_object(cube(x=555/2,y=555/4+555/16,z=555/2,width=555/8))


render_scene(scene2,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=500, fov=50, parallel=TRUE, clamp_value=5)
.

#Now group the cubes instead of the Cornell box, and rotate/translate them together
twocubes = cube(x=555/2,y=555/8,z=555/2,width=555/4) %>%
           add_object(cube(x=555/2, y=555/4 + 555/16, z=555/2, width=555/8))
scene3 = generate_cornell() %>%
         add_object(group_objects(twocubes, translate = c(0,50,0),angle = c(0,45,0),
         pivot_point = c(555/2,0,555/2)))

render_scene(scene3,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=500, fov=50, parallel=TRUE, clamp_value=5)


#Flatten and stretch the cubes together on two axes
scene4 = generate_cornell() %>%
         add_object(group_objects(twocubes, translate = c(0,-40,0),
                                  angle = c(0,45,0), scale = c(2,0.5,1),
                                  pivot_point = c(555/2,0,555/2)))

render_scene(scene4,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=500, fov=50, parallel=TRUE, clamp_value=5)


#Add another layer of grouping, including the Cornell box

scene4 %>%
  group_objects(pivot_point = c(555/2,555/2,555/2),scale=c(1.5,0.5,0.3), angle=c(-20,0,20)) %>%
   render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=509, fov=50, parallel=TRUE, clamp_value=5)
```

hair *Hair Material*

Description

Hair Material

Usage

```
hair(
  pigment = 1.3,
  red_pigment = 0,
  color = NA,
  sigma_a = NA,
  eta = 1.55,
  beta_m = 0.3,
  beta_n = 0.3,
  alpha = 2
)
```

Arguments

pigment	Default ‘1.3‘. Concentration of the eumelanin pigment in the hair. Blonde hair has concentrations around 0.3, brown around 1.3, and black around 8.
red_pigment	Default ‘0‘.Concentration of the pheomelanin pigment in the hair. Pheomelanin makes red hair red.
color	Default ‘NA‘. Approximate color. Overrides ‘pigment‘/‘redness‘ arguments.
sigma_a	Default ‘NA‘. Attenuation. Overrides ‘color‘ and ‘pigment‘/‘redness‘ arguments.
eta	Default ‘1.55‘. Index of refraction of the hair medium.
beta_m	Default ‘0.3‘. Longitudinal roughness of the hair. Should be between 0 and 1. This roughness controls the size and shape of the hair highlight.
beta_n	Default ‘0.3‘. Azimuthal roughness of the hair. Should be between 0 and 1.
alpha	Default ‘2‘. Angle of scales on the hair surface, in degrees.

Value

Single row of a tibble describing the hair material.

Examples

```
#Create a hairball

#Generate rendom points on a sphere
lengthval = 0.5
theta = acos(2*runif(10000)-1.0);
```

```
phi = 2*pi*(runif(10000))
bezier_list = list()

#Grow the hairs
for(i in 1:length(phi)) {
  pointval = c(sin(theta[i]) * sin(phi[i]),
               cos(theta[i]),
               sin(theta[i]) * cos(phi[i]))
  bezier_list[[i]] = bezier_curve(width=0.01, width_end=0.008,
                                  p1 = pointval,
                                  p2 = (1+(lengthval*0.33))*pointval,
                                  p3 = (1+(lengthval*0.66))*pointval,
                                  p4 = (1+(lengthval)) * pointval,
                                  material=hair(pigment = 0.3, red_pigment = 1.3,
                                                beta_m = 0.3, beta_n= 0.3),
                                  type="flat")
}
hairball = dplyr::bind_rows(bezier_list)

generate_ground(depth=-2,material=diffuse(color="grey20")) %>%
  add_object(sphere()) %>%
  add_object(hairball) %>%
 add_object(sphere(y=20,z=20,radius=5,material=light(color="white",intensity = 100))) %>%
  render_scene(samples=64, lookfrom=c(0,3,10),clamp_value = 10,
               fov=20)


#Specify the color directly and increase hair roughness
for(i in 1:length(phi)) {
  pointval = c(sin(theta[i]) * sin(phi[i]),
               cos(theta[i]),
               sin(theta[i]) * cos(phi[i]))
  bezier_list[[i]] = bezier_curve(width=0.01, width_end=0.008,
                                  p1 = pointval,
                                  p2 = (1+(lengthval*0.33))*pointval,
                                  p3 = (1+(lengthval*0.66))*pointval,
                                  p4 = (1+(lengthval)) * pointval,
                                  material=hair(color="purple",
                                                beta_m = 0.5, beta_n= 0.5),
                                  type="flat")
}
hairball = dplyr::bind_rows(bezier_list)
generate_ground(depth=-2,material=diffuse(color="grey20")) %>%
  add_object(sphere()) %>%
  add_object(hairball) %>%
 add_object(sphere(y=20,z=20,radius=5,material=light(color="white",intensity = 100))) %>%
  render_scene(samples=64, lookfrom=c(0,3,10),clamp_value = 10,
               fov=20)
```

`lambertian` *Lambertian Material (deprecated)*

Description

Lambertian Material (deprecated)

Usage

```
lambertian(...)
```

Arguments

`...`	Arguments to pass to diffuse() function.

Value

Single row of a tibble describing the diffuse material.

Examples

```
#Deprecated lambertian material. Will display a warning.

scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=lambertian()))
  render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=10,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
```

`light` *Light Material*

Description

Light Material

Usage

```
light(
  color = "#ffffff",
  intensity = 10,
  importance_sample = TRUE,
  spotlight_focus = NA,
  spotlight_width = 30,
  spotlight_start_falloff = 15,
  invisible = FALSE,
  image_texture = NA,
  image_repeat = 1,
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv"
)
```

Arguments

`color`	Default ‘white‘. The color of the light Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`intensity`	Default ‘NA‘. If a positive value, this will turn this object into a light emitting the value specified in ‘color‘ (ignoring other properties). Higher values will produce a brighter light.
`importance_sample`	Default ‘TRUE‘. Keeping this on for lights improves the convergence of the rendering algorithm, in most cases. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.
`spotlight_focus`	Default ‘NA‘, no spotlight. Otherwise, a length-3 numeric vector specifying the x/y/z coordinates that the spotlight should be focused on. Only works for spheres and rectangles.
`spotlight_width`	Default ‘30‘. Angular width of the spotlight.
`spotlight_start_falloff`	Default ‘15‘. Angle at which the light starts fading in intensity.
`invisible`	Default ‘FALSE‘. If ‘TRUE‘, the light itself will be invisible.
`image_texture`	Default ‘NA‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
`image_repeat`	Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.
`gradient_color`	Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.
`gradient_transpose`	Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.
`gradient_point_start`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.
`gradient_point_end`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.
`gradient_type`	Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.

Value

Single row of a tibble describing the light material.

Examples

```
#Generate the cornell box without a light and add a single white sphere to the center
scene = generate_cornell(light=FALSE) %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=light()))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Remove the light for direct camera rays, but keep the lighting
scene = generate_cornell(light=FALSE) %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,
             material=light(intensity=15,invisible=TRUE)))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#All gather around the orb
scene = generate_ground(material = diffuse(checkercolor="grey50")) %>%
  add_object(sphere(radius=0.5,material=light(intensity=5,color="red"))) %>%
  add_object(obj_model(r_obj(), z=-3,x=-1.5,y=-1, angle=c(0,45,0))) %>%
  add_object(pig(scale=0.3, x=1.5,z=-2,y=-1.5,angle=c(0,-135,0)))

render_scene(scene, samples=500, parallel=TRUE, clamp_value=10)
```

---

mesh3d_model *‘mesh3d‘ model*

Description

Load an ‘mesh3d‘ (or ‘shapelist3d‘) object, as specified in the ‘rgl‘ package.

Usage

```
mesh3d_model(
  mesh,
  x = 0,
  y = 0,
  z = 0,
  swap_yz = FALSE,
  reverse = FALSE,
  scale_mesh = 1,
  verbose = FALSE,
  override_material = FALSE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`mesh`	A ‘mesh3d‘ or ‘shapelist3d‘ object. Pulls the vertex, index, texture coordinates, normals, and material information. If the material references an image texture, the ‘mesh$material$texture‘ argument should be set to the image filename. The ‘mesh3d‘ format only supports one image texture per mesh. All quads will be triangulated.
`x`	Default ‘0‘. x-coordinate to offset the model.
`y`	Default ‘0‘. y-coordinate to offset the model.
`z`	Default ‘0‘. z-coordinate to offset the model.
`swap_yz`	Default ‘FALSE‘. Swap the Y and Z coordinates.
`reverse`	Default ‘FALSE‘. Reverse the orientation of the indices, flipping their normals.
`scale_mesh`	Default ‘1‘. Amount to scale the size of the mesh in all directions.
`verbose`	Default ‘FALSE‘. If ‘TRUE‘, prints information about the mesh to the console.
`override_material`	Default ‘FALSE‘. If ‘TRUE‘, overrides the material specified in the ‘mesh3d‘ object with the one specified in ‘material‘.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the mesh3d model in the scene.

Examples

```
#Load a mesh3d object (from the Rvcg) and render it:
if(length(find.package("Rvcg", quiet=TRUE)) > 0) {
  library(Rvcg)
  data(humface)
  generate_studio() %>%
    add_object(mesh3d_model(humface,y=-0.3,x=0,z=0,
                          material=glossy(color="dodgerblue4"), scale_mesh = 1/70)) %>%
    add_object(sphere(y=5,x=5,z=5,material=light(intensity=50))) %>%
    render_scene(samples=500,width=800,height=800,
                 lookat = c(0,0.5,1), aperture=0.0)
}
```

metal *Metallic Material*

Description

Metallic Material

Usage

```
metal(
  color = "#ffffff",
  eta = 0,
  kappa = 0,
  fuzz = 0,
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = NA,
  image_repeat = 1,
  alpha_texture = NA,
  bump_texture = NA,
  bump_intensity = 1,
  importance_sample = FALSE
)
```

Arguments

color	Default ‘white‘. The color of the sphere. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
eta	Default ‘0‘. Wavelength dependent refractivity of the material (red, green, and blue channels). If single number, will be repeated across all three channels.

kappa	Default ‘0‘. Wavelength dependent absorption of the material (red, green, and blue channels). If single number, will be repeated across all three channels.
fuzz	Default ‘0‘. Deprecated–Use the microfacet material instead, as it is designed for rough metals. The roughness of the metallic surface. Maximum ‘1‘.
checkercolor	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
checkerperiod	Default ‘3‘. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
noise	Default ‘0‘. If not ‘0‘, covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
noisephase	Default ‘0‘. The phase of the noise. The noise will repeat at ‘360‘.
noiseintensity	Default ‘10‘. Intensity of the noise.
noisecolor	Default ‘#000000‘. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
gradient_color	Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.
gradient_transpose	Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.
gradient_point_start	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.
gradient_point_end	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.
gradient_type	Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.
image_texture	Default ‘NA‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
image_repeat	Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.
alpha_texture	Default ‘NA‘. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.
bump_texture	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
bump_intensity	Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.

`importance_sample`
: Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the metallic material.

Examples

```
# Generate the cornell box with a single chrome sphere in the center. For other metals,
# See the website refractiveindex.info for eta and k data, use wavelengths 5
# 80nm (R), 530nm (G), and 430nm (B).
scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,
  material=metal(eta=c(3.2176,3.1029,2.1839), k = c(3.3018,3.33,3.0339))))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=50,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)

#Add an aluminum rotated shiny metal block
scene = scene %>%
  add_object(cube(x=380,y=150/2,z=200,xwidth=150,ywidth=150,zwidth=150,
 material = metal(eta = c(1.07,0.8946,0.523), k = c(6.7144,6.188,4.95)),angle=c(0,45,0)))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)

#Add a copper metal cube
scene = scene %>%
  add_object(cube(x=150,y=150/2,z=300,xwidth=150,ywidth=150,zwidth=150,
                  material = metal(eta = c(0.497,0.8231,1.338),
                                   k = c(2.898,2.476,2.298)),
                  angle=c(0,-30,0)))

render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)


#Finally, let's add a lead pipe
scene2 = scene %>%
  add_object(cylinder(x=450,y=200,z=400,length=400,radius=30,
                  material = metal(eta = c(1.44,1.78,1.9),
                                   k = c(3.18,3.36,3.43)),
                  angle=c(0,-30,0)))

render_scene(scene2, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
```

`microfacet` *Microfacet Material*

Description

Microfacet Material

Usage

```
microfacet(
  color = "white",
  roughness = 1e-04,
  transmission = FALSE,
  eta = 0,
  kappa = 0,
  microfacet = "tbr",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = NA,
  image_repeat = 1,
  alpha_texture = NA,
  bump_texture = NA,
  bump_intensity = 1,
  roughness_texture = NA,
  roughness_range = c(1e-04, 0.2),
  roughness_flip = FALSE,
  importance_sample = FALSE
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`roughness`	Default ‘0.0001‘. Roughness of the surface, between ‘0‘ (smooth) and ‘1‘ (diffuse). Can be either a single number, or two numbers indicating an anisotropic distribution of normals. ‘0‘ is a smooth surface, while ‘1‘ is extremely rough. This can be used to create a wide-variety of materials (e.g. ‘0-0.01‘ is specular metal, ‘0.02‘-‘0.1‘ is brushed metal, ‘0.1‘-‘0.3‘ is a rough metallic surface ,

	‘0.3‘-‘0.5‘ is diffuse, and above that is a rough satin-like material). Two numbers will specify the x and y roughness separately (e.g. ‘roughness = c(0.01, 0.001)‘ gives an etched metal effect). If ‘0‘, this defaults to the ‘metal()‘ material for faster evaluation.
`transmission`	Default ‘FALSE‘. If ‘TRUE‘, this material will be a rough dielectric instead of a rough metallic surface.
`eta`	Default ‘0‘. Wavelength dependent refractivity of the material (red, green, and blue channels). If single number, will be repeated across all three channels. If ‘transmission = TRUE‘, this is a single value representing the index of refraction of the material.
`kappa`	Default ‘0‘. Wavelength dependent absorption of the material (red, green, and blue channels). If single number, will be repeated across all three channels. If ‘transmission = TRUE‘, this length-3 vector specifies the attenuation of the dielectric (analogous to the dielectric ‘attenuation‘ argument).
`microfacet`	Default ‘tbr‘. Type of microfacet distribution. Alternative option ‘beckmann‘.
`checkercolor`	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkerperiod`	Default ‘3‘. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
`noise`	Default ‘0‘. If not ‘0‘, covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
`noisephase`	Default ‘0‘. The phase of the noise. The noise will repeat at ‘360‘.
`noiseintensity`	Default ‘10‘. Intensity of the noise.
`noisecolor`	Default ‘#000000‘. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`gradient_color`	Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.
`gradient_transpose`	Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.
`gradient_point_start`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.
`gradient_point_end`	Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.
`gradient_type`	Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.

`image_texture`	Default ‘NA‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
`image_repeat`	Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.
`alpha_texture`	Default ‘NA‘. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.
`bump_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
`bump_intensity`	Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.
`roughness_texture`	Default ‘NA‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a roughness map for the surface.
`roughness_range`	Default ‘ c(0.0001, 0.2)‘. This is a length-2 vector that specifies the range of roughness values that the ‘roughness_texture‘ can take.
`roughness_flip`	Default ‘FALSE‘. Setting this to ‘TRUE‘ flips the roughness values specified in the ‘roughness_texture‘ so high values are now low values and vice versa.
`importance_sample`	Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the microfacet material.

Examples

```
# Generate a golden egg, using eta and kappa taken from physical measurements
# See the website refractiveindex.info for eta and k data, use
# wavelengths 580nm (R), 530nm (G), and 430nm (B).

generate_cornell() %>%
  add_object(ellipsoid(x=555/2,555/2,y=150, a=100,b=150,c=100,
             material=microfacet(roughness=0.1,
                         eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
             aperture=0, fov=40, parallel=TRUE,clamp_value=10)

#Make the roughness anisotropic (either horizontal or vertical), adding an extra light in front
#to show off the different microfacet orientations
generate_cornell() %>%
  add_object(sphere(x=555/2,z=50,y=75,radius=20,material=light())) %>%
  add_object(ellipsoid(x=555-150,555/2,y=150, a=100,b=150,c=100,
             material=microfacet(roughness=c(0.3,0.1),
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 add_object(ellipsoid(x=150,555/2,y=150, a=100,b=150,c=100,
            material=microfacet(roughness=c(0.1,0.3),
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
            aperture=0, fov=40,  parallel=TRUE,clamp_value=10)

#Render a rough silver R with a smaller golden egg in front
generate_cornell() %>%
  add_object(obj_model(r_obj(),x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
            material=microfacet(roughness=0.2,
                         eta=c(1.1583,0.9302,0.5996), kappa=c(6.9650,6.396,5.332)))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
            material=microfacet(roughness=0.1,
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
            aperture=0, fov=40, parallel=TRUE,clamp_value=10)

#Increase the roughness
generate_cornell() %>%
  add_object(obj_model(r_obj(),x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
            material=microfacet(roughness=0.5,
                         eta=c(1.1583,0.9302,0.5996), kappa=c(6.9650,6.396,5.332)))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
            material=microfacet(roughness=0.3,
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
            aperture=0, fov=40, parallel=TRUE,clamp_value=10)

 #Use transmission for a rough dielectric

generate_cornell() %>%
  add_object(obj_model(r_obj(),x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
            material=microfacet(roughness=0.3, transmission=T, eta=1.6))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
            material=microfacet(roughness=0.3, transmission=T, eta=1.6))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=500,
            aperture=0, fov=40, parallel=TRUE,clamp_value=10, min_variance=1e-6)
```

obj_model *'obj' File Object*

Description

Load an obj file via a filepath. Currently only supports the diffuse texture with the 'texture' argument. Note: light importance sampling currently not supported for this shape.

Usage

```
obj_model(
  filename,
  x = 0,
  y = 0,
  z = 0,
  scale_obj = 1,
  texture = FALSE,
  vertex_colors = FALSE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`filename`	Filename and path to the ‘obj‘ file. Can also be a ‘txt‘ file, if it’s in the correct ‘obj‘ internally.
`x`	Default ‘0‘. x-coordinate to offset the model.
`y`	Default ‘0‘. y-coordinate to offset the model.
`z`	Default ‘0‘. z-coordinate to offset the model.
`scale_obj`	Default ‘1‘. Amount to scale the model. Use this to scale the object up or down on all axes, as it is more robust to numerical precision errors than the generic scale option.
`texture`	Default ‘FALSE‘. Whether to load the obj file texture.
`vertex_colors`	Default ‘FALSE‘. Set to ‘TRUE‘ if the OBJ file has vertex colors to apply them to the model.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the obj model in the scene.

Examples

```
#Load the included example R object file, by calling the r_obj() function. This
#returns the local file path to the `r.txt` obj file. The file extension is "txt"
#due to package constraints, but the file contents are identical and it does not
#affect the function.


generate_ground(material = diffuse(checkercolor = "grey50")) %>%
  add_object(obj_model(y = -0.8, filename = r_obj(),
                       material = microfacet(color = "gold", roughness = 0.05))) %>%
  add_object(obj_model(x = 1.8, y = -0.8, filename = r_obj(),
                       material = diffuse(color = "dodgerblue"))) %>%
  add_object(obj_model(x = -1.8, y = -0.8, filename = r_obj() ,
                       material = dielectric(attenuation = c(1,0.3,1)*2))) %>%
  add_object(sphere(z = 20, x = 20, y = 20, radius = 10,
                    material = light(intensity = 10))) %>%
  render_scene(parallel = TRUE, samples = 500, aperture = 0.05,
               fov = 32, lookfrom = c(0, 2, 10))



#Use scale_obj to make objects bigger--this is more robust than the generic scale argument.

generate_ground(material = diffuse(checkercolor = "grey50")) %>%
  add_object(obj_model(y = -0.8, filename = r_obj(), scale_obj = 2,
                 material = diffuse(noise = TRUE, noiseintensity = 10,noisephase=45))) %>%
  add_object(sphere(z = 20, x = 20, y = 20, radius = 10,
                    material = light(intensity = 10))) %>%
  render_scene(parallel = TRUE, samples = 500, ambient = TRUE,
               backgroundhigh="blue", backgroundlow="red",
               aperture = 0.05, fov = 32, lookfrom = c(0, 2, 10),
               lookat = c(0,1,0))
```

`path` *Path Object*

Description

Either a closed or open path made up of bezier curves that go through the specified points (with continuous first and second derivatives), or straight line segments.

Usage

```
path(
  points,
  x = 0,
  y = 0,
  z = 0,
  closed = FALSE,
  straight = FALSE,
  precomputed_control_points = FALSE,
  width = 0.1,
  width_end = NA,
  u_min = 0,
  u_max = 1,
  type = "cylinder",
  normal = c(0, 0, -1),
  normal_end = NA,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`points`	Either a list of length-3 numeric vectors or 3-column matrix/data.frame specifying the x/y/z points that the path should go through.
`x`	Default ‘0‘. x-coordinate offset for the path.
`y`	Default ‘0‘. y-coordinate offset for the path.
`z`	Default ‘0‘. z-coordinate offset for the path.
`closed`	Default ‘FALSE‘. If ‘TRUE‘, a final segment will be added that connects the first and last points (unless they are already the same). Note: This final connection does not have continuous 1st and 2nd derivatives.
`straight`	Default ‘FALSE‘. If ‘TRUE‘, straight lines will be used to connect the points instead of bezier curves.
`precomputed_control_points`	Default ‘FALSE‘. If ‘TRUE‘, ‘points‘ argument will expect a list of control points calculated with the internal rayrender function ‘rayrender:::calculate_control_points()‘.
`width`	Default ‘0.1‘. Curve width.
`width_end`	Default ‘NA‘. Width at end of path. Same as ‘width‘, unless specified.
`u_min`	Default ‘0‘. Minimum parametric coordinate for the path.
`u_max`	Default ‘1‘. Maximum parametric coordinate for the path.
`type`	Default ‘cylinder‘. Other options are ‘flat‘ and ‘ribbon‘.
`normal`	Default ‘c(0,0,-1)‘. Orientation surface normal for the start of ribbon curves.
`normal_end`	Default ‘NA‘. Orientation surface normal for the start of ribbon curves. If not specified, same as ‘normal‘.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
#Generate a wavy line, showing the line goes through the specified points:
wave = list(c(-2,1,0),c(-1,-1,0),c(0,1,0),c(1,-1,0),c(2,1,0))
point_mat = glossy(color="green")
generate_studio(depth=-1.5) %>%
  add_object(path(points = wave,material=glossy(color="red"))) %>%
  add_object(sphere(x=-2,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=-1,y=-1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=0,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=1,y=-1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=2,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(z=5,x=5,y=5,radius=2,material=light(intensity=15))) %>%
  render_scene(samples=500, clamp_value=10,fov=30)

#Here we use straight lines by setting `straight = TRUE`:
generate_studio(depth=-1.5) %>%
  add_object(path(points = wave,straight = TRUE, material=glossy(color="red"))) %>%
  add_object(sphere(z=5,x=5,y=5,radius=2,material=light(intensity=15))) %>%
  render_scene(samples=500, clamp_value=10,fov=30)

#We can also pass a matrix of values, specifying the x/y/z coordinates. Here,
#we'll create a random curve:
set.seed(21)
random_mat = matrix(runif(3*9)*2-1, ncol=3)
generate_studio(depth=-1.5) %>%
  add_object(path(points=random_mat, material=glossy(color="red"))) %>%
  add_object(sphere(y=5,radius=1,material=light(intensity=30))) %>%
  render_scene(samples=500, clamp_value=10)

#We can ensure the curve is closed by setting `closed = TRUE`
generate_studio(depth=-1.5) %>%
  add_object(path(points=random_mat, closed = TRUE, material=glossy(color="red"))) %>%
  add_object(sphere(y=5,radius=1,material=light(intensity=30))) %>%
  render_scene(samples=500, clamp_value=10)

#Finally, let's render a pretzel to show how you can render just a subset of the curve:
pretzel = list(c(-0.8,-0.5,0.1),c(0,-0.2,-0.1),c(0,0.3,0.1),c(-0.5,0.5,0.1), c(-0.6,-0.5,-0.1),
               c(0,-0.8,-0.1),
          c(0.6,-0.5,-0.1),c(0.5,0.5,-0.1), c(0,0.3,-0.1),c(-0,-0.2,0.1), c(0.8,-0.5,0.1))
```

```
#Render the full pretzel:
generate_studio(depth = -1.1) %>%
  add_object(path(pretzel, width=0.17,  material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=500, clamp_value=10)

#Here, we'll render only the first third of the pretzel by setting `u_max = 0.33`
generate_studio(depth = -1.1) %>%
 add_object(path(pretzel, width=0.17, u_max=0.33, material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=500, clamp_value=10)

#Here's the last third, by setting `u_min = 0.66`
generate_studio(depth = -1.1) %>%
 add_object(path(pretzel, width=0.17, u_min=0.66, material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=500, clamp_value=10)

#Here's the full pretzel, decomposed into thirds using the u_min and u_max coordinates
generate_studio(depth = -1.1) %>%
  add_object(path(pretzel, width=0.17, u_max=0.33, x = -0.8, y =0.6,
                  material = glossy(color="#db5b00"))) %>%
  add_object(path(pretzel, width=0.17, u_min=0.66, x = 0.8, y =0.6,
                  material = glossy(color="#db5b00"))) %>%
  add_object(path(pretzel, width=0.17, u_min=0.33, u_max=0.66, x=0,
                  material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=500, clamp_value=10, lookfrom=c(0,3,10))
```

pig *Pig Object*

Description

Pig Object

Usage

```
pig(
  x = 0,
  y = 0,
  z = 0,
  emotion = "neutral",
  spider = FALSE,
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  scale = c(1, 1, 1),
  diffuse_sigma = 0
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the pig.
`y`	Default ‘0‘. y-coordinate of the center of the pig.
`z`	Default ‘0‘. z-coordinate of the center of the pig.
`emotion`	Default ‘neutral‘. Other options include ‘skeptical‘, ‘worried‘, and ‘angry‘.
`spider`	Default ‘FALSE‘. Spiderpig.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly.
`diffuse_sigma`	Default ‘0‘. Controls the Oren-Nayar sigma parameter for the pig’s diffuse material.

Value

Single row of a tibble describing the pig in the scene.

Examples

```
#Generate a pig in the cornell box.


generate_cornell() %>%
  add_object(pig(x=555/2,z=555/2,y=120,
  scale=c(80,80,80), angle = c(0,135,0))) %>%
  render_scene(parallel=TRUE, samples=400,clamp_value=10)

# Show the pig staring into a mirror, worried
generate_cornell() %>%
  add_object(pig(x=555/2-70,z=555/2+50,y=120,scale=c(80,80,80),
                 angle = c(0,-40,0), emotion = "worried")) %>%
  add_object(cube(x=450,z=450,y=250, ywidth=500, xwidth=200,
                  angle = c(0,45,0), material = metal())) %>%
  render_scene(parallel=TRUE, samples=500,clamp_value=10)

# Render many small pigs facing random directions, with an evil pig overlord
set.seed(1)
lots_of_pigs = list()
for(i in 1:10) {
  lots_of_pigs[[i]] = pig(x=50 + 450 * runif(1), z = 50 + 450 * runif(1), y=50,
                    scale = c(30,30,30), angle = c(0,360*runif(1),0), emotion = "worried")
}

many_pigs_scene = do.call(rbind, lots_of_pigs) %>%
 add_object(generate_cornell(lightintensity=30, lightwidth=100)) %>%
 add_object(pig(z=500,x=555/2,y=350, emotion = "angry",
            scale=c(100,100,100),angle=c(-30,90,0), order_rotation=c(3,2,1)))

render_scene(many_pigs_scene,parallel=TRUE,clamp_value=10, samples=500)

#Render spiderpig
generate_studio() %>%
  add_object(pig(y=-1,angle=c(0,-100,0), scale=1/2,spider=TRUE)) %>%
  add_object(sphere(y=5,z=5,x=5,material=light(intensity=100))) %>%
  render_scene(samples=500,lookfrom=c(0,2,10),clamp_value=10)
```

ply_model *'ply' File Object*

Description

Load an PLY file via a filepath. Note: light importance sampling currently not supported for this shape.

Usage

```
ply_model(
  filename,
  x = 0,
  y = 0,
  z = 0,
  scale_ply = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`filename`	Filename and path to the 'ply' file. Can also be a 'txt' file, if it's in the correct 'ply' internally.
`x`	Default '0'. x-coordinate to offset the model.
`y`	Default '0'. y-coordinate to offset the model.
`z`	Default '0'. z-coordinate to offset the model.
`scale_ply`	Default '1'. Amount to scale the model. Use this to scale the object up or down on all axes, as it is more robust to numerical precision errors than the generic scale option.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.

`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the obj model in the scene.

Examples

```
#See the documentation for `obj_model()`--no example PLY models are included with this package,
#but the process of loading a model is the same (without support for vertex colors).
```

render_animation *Render Animation*

Description

Takes the scene description and renders an image, either to the device or to a filename.

Usage

```
render_animation(
  scene,
  camera_motion,
  start_frame = 1,
  width = 400,
  height = 400,
  samples = 100,
  min_variance = 5e-05,
  min_adaptive_size = 8,
  sample_method = "sobol",
  max_depth = 50,
  roulette_active_depth = 10,
  ambient_light = FALSE,
  clamp_value = Inf,
  filename = "rayimage",
  backgroundhigh = "#80b4ff",
  backgroundlow = "#ffffff",
  shutteropen = 0,
  shutterclose = 1,
  focal_distance = NULL,
  ortho_dimensions = c(1, 1),
  tonemap = "gamma",
  bloom = TRUE,
  parallel = TRUE,
  bvh_type = "sah",
  environment_light = NULL,
  rotate_env = 0,
  intensity_env = 1,
  debug_channel = "none",
  return_raw_array = FALSE,
  progress = interactive(),
  verbose = FALSE,
  preview_light_direction = c(0, -1, 0),
  preview_exponent = 6
)
```

Arguments

`scene`	Tibble of object locations and properties.
`camera_motion`	Data frame of camera motion vectors, calculated with ‘generate_camera_motion()‘.
`start_frame`	Default ‘1‘. Frame to start the animation.
`width`	Default ‘400‘. Width of the render, in pixels.
`height`	Default ‘400‘. Height of the render, in pixels.
`samples`	Default ‘100‘. The maximum number of samples for each pixel. If this is a length-2 vector and the ‘sample_method‘ is ‘stratified‘, this will control the number of strata in each dimension. The total number of samples in this case will be the product of the two numbers.
`min_variance`	Default ‘0.00005‘. Minimum acceptable variance for a block of pixels for the adaptive sampler. Smaller numbers give higher quality images, at the expense of longer rendering times. If this is set to zero, the adaptive sampler will be turned off and the renderer will use the maximum number of samples everywhere.
`min_adaptive_size`	Default ‘8‘. Width of the minimum block size in the adaptive sampler.
`sample_method`	Default ‘sobol‘. The type of sampling method used to generate random numbers. The other options are ‘random‘ (worst quality but simple), ‘stratified‘ (only implemented for completion), and ‘sobol_blue‘ (best option for sample counts below 256).
`max_depth`	Default ‘50‘. Maximum number of bounces a ray can make in a scene.
`roulette_active_depth`	Default ‘10‘. Number of ray bounces until a ray can stop bouncing via Russian roulette.
`ambient_light`	Default ‘FALSE‘, unless there are no emitting objects in the scene. If ‘TRUE‘, the background will be a gradient varying from ‘backgroundhigh‘ directly up (+y) to ‘backgroundlow‘ directly down (-y).

`clamp_value`	Default ‘Inf‘. If a bright light or a reflective material is in the scene, occasionally there will be bright spots that will not go away even with a large number of samples. These can be removed (at the cost of slightly darkening the image) by setting this to a small number greater than 1.
`filename`	Default ‘NULL‘. If present, the renderer will write to the filename instead of the current device.
`backgroundhigh`	Default ‘#80b4ff‘. The "high" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`backgroundlow`	Default ‘#ffffff‘. The "low" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`shutteropen`	Default ‘0‘. Time at which the shutter is open. Only affects moving objects.
`shutterclose`	Default ‘1‘. Time at which the shutter is open. Only affects moving objects.
`focal_distance`	Default ‘NULL‘, automatically set to the ‘lookfrom-lookat‘ distance unless otherwise specified.
`ortho_dimensions`	Default ‘c(1,1)‘. Width and height of the orthographic camera. Will only be used if ‘fov = 0‘.
`tonemap`	Default ‘gamma‘. Choose the tone mapping function, Default ‘gamma‘ solely adjusts for gamma and clamps values greater than 1 to 1. ‘reinhold‘ scales values by their individual color channels ‘color/(1+color)‘ and then performs the gamma adjustment. ‘uncharted‘ uses the mapping developed for Uncharted 2 by John Hable. ‘hbd‘ uses an optimized formula by Jim Hejl and Richard Burgess-Dawson. Note: If set to anything other than ‘gamma‘, objects with material ‘light()‘ may not be anti-aliased. If ‘raw‘, the raw array of HDR values will be returned, rather than an image or a plot.
`bloom`	Default ‘TRUE‘. Set to ‘FALSE‘ to get the raw, pathtraced image. Otherwise, this performs a convolution of the HDR image of the scene with a sharp, long-tailed exponential kernel, which does not visibly affect dimly pixels, but does result in emitters light slightly bleeding into adjacent pixels. This provides an antialiasing effect for lights, even when tonemapping the image. Pass in a matrix to specify the convolution kernel manually, or a positive number to control the intensity of the bloom (higher number = more bloom).
`parallel`	Default ‘FALSE‘. If ‘TRUE‘, it will use all available cores to render the image (or the number specified in ‘options("cores")‘ if that option is not ‘NULL‘).
`bvh_type`	Default ‘"sah"‘, "surface area heuristic". Method of building the bounding volume hierarchy structure used when rendering. Other option is "equal", which splits tree into groups of equal size.
`environment_light`	Default ‘NULL‘. An image to be used for the background for rays that escape the scene. Supports both HDR (‘.hdr‘) and low-dynamic range (‘.png‘, ‘.jpg‘) images.
`rotate_env`	Default ‘0‘. The number of degrees to rotate the environment map around the scene.

intensity_env	Default '1'. The amount to increase the intensity of the environment lighting. Useful if using a LDR (JPEG or PNG) image as an environment map.
debug_channel	Default 'none'. If 'depth', function will return a depth map of rays into the scene instead of an image. If 'normals', function will return an image of scene normals, mapped from 0 to 1. If 'uv', function will return an image of the uv coords. If 'variance', function will return an image showing the number of samples needed to take for each block to converge. If 'dpdu' or 'dpdv', function will return an image showing the differential 'u' and 'u' coordinates. If 'color', function will return the raw albedo values (with white for 'metal' and 'dielectric' materials). If 'preview', an image rendered with 'render_preview()' will be returned.
return_raw_array	Default 'FALSE'. If 'TRUE', function will return raw array with RGB intensity information.
progress	Default 'TRUE' if interactive session, 'FALSE' otherwise.
verbose	Default 'FALSE'. Prints information and timing information about scene construction and raytracing progress.
preview_light_direction	Default 'c(0,-1,0)'. Vector specifying the orientation for the global light using for phong shading.
preview_exponent	Default '6'. Phong exponent.

Value

Raytraced plot to current device, or an image saved to a file.

Examples

```
#Create and animate flying through a scene on a simulated roller coaster

set.seed(3)
elliplist = list()
ellip_colors = rainbow(8)
for(i in 1:1200) {
  elliplist[[i]] = ellipsoid(x=10*runif(1)-5,y=10*runif(1)-5,z=10*runif(1)-5,
                             angle = 360*runif(3), a=0.1,b=0.05,c=0.1,
                             material=glossy(color=sample(ellip_colors,1)))
}
ellip_scene = do.call(rbind, elliplist)

camera_pos = list(c(0,1,15),c(5,-5,5),c(-5,5,-5),c(0,1,-15))

#Plot the camera path and render from above using the path object:
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,20,0), width=800,height=800,samples=32,
               camera_up = c(0,0,1),
               fov=80)

#Side view
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(20,0,0),width=800,height=800,samples=32,
                fov=80)

#View from the start
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,1.5,16),width=800,height=800,samples=32,
                fov=80)

#Generate Camera movement, setting the lookat position to be same as camera position, but offset
#slightly in front. We'll render 12 frames, but you'd likely want more in a real animation.

camera_motion =  generate_camera_motion(positions = camera_pos, lookats = camera_pos,
                                       offset_lookat = 1, fovs=80, frames=12)

#This returns a data frame of individual camera positions, interpolated by cubic bezier curves.
camera_motion

#Pass NA filename to plot to the device. We'll keep the path and offset it slightly to see
#where we're going. This results in a "roller coaster" effect.
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(obj_model(r_obj(),x=10,y=-10,scale_obj=3, angle=c(0,-45,0),
                      material=dielectric(attenuation=c(1,1,0.3)))) %>%
  add_object(pig(x=-7,y=10,z=-5,scale=1,angle=c(0,-45,80),emotion="angry")) %>%
  add_object(pig(x=0,y=-0.25,z=-15,scale=1,angle=c(0,225,-20),
                emotion="angry", spider=TRUE)) %>%
  add_object(path(camera_pos, y=-0.2,material=diffuse(color="red"))) %>%
  render_animation(filename = NA, camera_motion = camera_motion, samples=100,
                  sample_method="sobol_blue",
                  clamp_value=10, width=400, height=400)
```

`render_preview` *Render Preview*

Description

Takes the scene description and renders an image, either to the device or to a filename.

Usage

```
render_preview(..., light_direction = c(0, -1, 0), exponent = 6)
```

Arguments

`...`	All arguments that would be passed to ‘render_scene()‘.
`light_direction`	Default ‘c(0,-1,0)‘. Vector specifying the orientation for the global light using for phong shading.
`exponent`	Default ‘6‘. Phong exponent.

Value

Raytraced plot to current device, or an image saved to a file.

Examples

```
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview()

#Change the light direction
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview(light_direction = c(-1,-1,0))

#Change the Phong exponent
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview(light_direction = c(-1,-1,0), exponent=100)
```

`render_scene` *Render Scene*

Description

Takes the scene description and renders an image, either to the device or to a filename.

Usage

```
render_scene(
  scene,
  width = 400,
  height = 400,
  fov = 20,
  samples = 100,
  min_variance = 5e-05,
  min_adaptive_size = 8,
  sample_method = "sobol",
  max_depth = NA,
  roulette_active_depth = 100,
  ambient_light = FALSE,
  lookfrom = c(0, 1, 10),
  lookat = c(0, 0, 0),
  camera_up = c(0, 1, 0),
  aperture = 0.1,
  clamp_value = Inf,
  filename = NULL,
  backgroundhigh = "#80b4ff",
  backgroundlow = "#ffffff",
  shutteropen = 0,
  shutterclose = 1,
  focal_distance = NULL,
  ortho_dimensions = c(1, 1),
  tonemap = "gamma",
  bloom = TRUE,
  parallel = TRUE,
  bvh_type = "sah",
  environment_light = NULL,
  rotate_env = 0,
  intensity_env = 1,
  debug_channel = "none",
  return_raw_array = FALSE,
  progress = interactive(),
  verbose = FALSE
)
```

Arguments

`scene`	Tibble of object locations and properties.
`width`	Default ‘400‘. Width of the render, in pixels.
`height`	Default ‘400‘. Height of the render, in pixels.
`fov`	Default ‘20‘. Field of view, in degrees. If this is ‘0‘, the camera will use an orthographic projection. The size of the plane used to create the orthographic projection is given in argument ‘ortho_dimensions‘. From ‘0‘ to ‘180‘, this uses a perspective projections. If this value is ‘360‘, a 360 degree environment image will be rendered.
`samples`	Default ‘100‘. The maximum number of samples for each pixel. If this is a length-2 vector and the ‘sample_method‘ is ‘stratified‘, this will control the number of strata in each dimension. The total number of samples in this case will be the product of the two numbers.
`min_variance`	Default ‘0.00005‘. Minimum acceptable variance for a block of pixels for the adaptive sampler. Smaller numbers give higher quality images, at the expense of

	longer rendering times. If this is set to zero, the adaptive sampler will be turned off and the renderer will use the maximum number of samples everywhere.
`min_adaptive_size`	Default ‘8‘. Width of the minimum block size in the adaptive sampler.
`sample_method`	Default ‘sobol‘. The type of sampling method used to generate random numbers. The other options are ‘random‘ (worst quality but fastest), ‘stratified‘ (only implemented for completion), ‘sobol_blue‘ (best option for sample counts below 256), and ‘sobol‘ (slowest but best quality, better than ‘sobol_blue‘ for sample counts greater than 256).
`max_depth`	Default ‘NA‘, automatically sets to 50. Maximum number of bounces a ray can make in a scene. Alternatively, if a debugging option is chosen, this sets the bounce to query the debugging parameter (only for some options).
`roulette_active_depth`	Default ‘100‘. Number of ray bounces until a ray can stop bouncing via Russian roulette.
`ambient_light`	Default ‘FALSE‘, unless there are no emitting objects in the scene. If ‘TRUE‘, the background will be a gradient varying from ‘backgroundhigh‘ directly up (+y) to ‘backgroundlow‘ directly down (-y).
`lookfrom`	Default ‘c(0,1,10)‘. Location of the camera.
`lookat`	Default ‘c(0,0,0)‘. Location where the camera is pointed.
`camera_up`	Default ‘c(0,1,0)‘. Vector indicating the "up" position of the camera.
`aperture`	Default ‘0.1‘. Aperture of the camera. Smaller numbers will increase depth of field, causing less blurring in areas not in focus.
`clamp_value`	Default ‘Inf‘. If a bright light or a reflective material is in the scene, occasionally there will be bright spots that will not go away even with a large number of samples. These can be removed (at the cost of slightly darkening the image) by setting this to a small number greater than 1.
`filename`	Default ‘NULL‘. If present, the renderer will write to the filename instead of the current device.
`backgroundhigh`	Default ‘#80b4ff‘. The "high" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`backgroundlow`	Default ‘#ffffff‘. The "low" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`shutteropen`	Default ‘0‘. Time at which the shutter is open. Only affects moving objects.
`shutterclose`	Default ‘1‘. Time at which the shutter is open. Only affects moving objects.
`focal_distance`	Default ‘NULL‘, automatically set to the ‘lookfrom-lookat‘ distance unless otherwise specified.
`ortho_dimensions`	Default ‘c(1,1)‘. Width and height of the orthographic camera. Will only be used if ‘fov = 0‘.

`tonemap`	Default 'gamma'. Choose the tone mapping function, Default 'gamma' solely adjusts for gamma and clamps values greater than 1 to 1. 'reinhold' scales values by their individual color channels 'color/(1+color)' and then performs the gamma adjustment. 'uncharted' uses the mapping developed for Uncharted 2 by John Hable. 'hbd' uses an optimized formula by Jim Hejl and Richard Burgess-Dawson. Note: If set to anything other than 'gamma', objects with material 'light()' may not be anti-aliased. If 'raw', the raw array of HDR values will be returned, rather than an image or a plot.
`bloom`	Default 'TRUE'. Set to 'FALSE' to get the raw, pathtraced image. Otherwise, this performs a convolution of the HDR image of the scene with a sharp, long-tailed exponential kernel, which does not visibly affect dimly pixels, but does result in emitters light slightly bleeding into adjacent pixels. This provides an antialiasing effect for lights, even when tonemapping the image. Pass in a matrix to specify the convolution kernel manually, or a positive number to control the intensity of the bloom (higher number = more bloom).
`parallel`	Default 'FALSE'. If 'TRUE', it will use all available cores to render the image (or the number specified in 'options("cores")' if that option is not 'NULL').
`bvh_type`	Default '"sah"', "surface area heuristic". Method of building the bounding volume hierarchy structure used when rendering. Other option is "equal", which splits tree into groups of equal size.
`environment_light`	Default 'NULL'. An image to be used for the background for rays that escape the scene. Supports both HDR ('.hdr') and low-dynamic range ('.png', '.jpg') images.
`rotate_env`	Default '0'. The number of degrees to rotate the environment map around the scene.
`intensity_env`	Default '1'. The amount to increase the intensity of the environment lighting. Useful if using a LDR (JPEG or PNG) image as an environment map.
`debug_channel`	Default 'none'. If 'depth', function will return a depth map of rays into the scene instead of an image. If 'normals', function will return an image of scene normals, mapped from 0 to 1. If 'uv', function will return an image of the uv coords. If 'variance', function will return an image showing the number of samples needed to take for each block to converge. If 'dpdu' or 'dpdv', function will return an image showing the differential 'u' and 'u' coordinates. If 'color', function will return the raw albedo values (with white for 'metal' and 'dielectric' materials).
`return_raw_array`	Default 'FALSE'. If 'TRUE', function will return raw array with RGB intensity information.
`progress`	Default 'TRUE' if interactive session, 'FALSE' otherwise.
`verbose`	Default 'FALSE'. Prints information and timing information about scene construction and raytracing progress.

Value

Raytraced plot to current device, or an image saved to a file.

Examples

```
#Generate a large checkered sphere as the ground

scene = generate_ground(depth=-0.5, material = diffuse(color="white", checkercolor="darkgreen"))
render_scene(scene,parallel=TRUE,samples=500,sample_method="sobol")


#Add a sphere to the center

scene = scene %>%
  add_object(sphere(x=0,y=0,z=0,radius=0.5,material = diffuse(color=c(1,0,1))))
render_scene(scene,fov=20,parallel=TRUE,samples=500)


#Add a marbled cube

scene = scene %>%
  add_object(cube(x=1.1,y=0,z=0,material = diffuse(noise=3)))
render_scene(scene,fov=20,parallel=TRUE,samples=500)


#Add a metallic gold sphere, using stratified sampling for a higher quality render

scene = scene %>%
  add_object(sphere(x=-1.1,y=0,z=0,radius=0.5,material = metal(color="gold",fuzz=0.1)))
render_scene(scene,fov=20,parallel=TRUE,samples=500)


#Lower the number of samples to render more quickly (here, we also use only one core).

render_scene(scene, samples=4)


#Add a floating R plot using the iris dataset as a png onto a floating 2D rectangle


tempfileplot = tempfile()
png(filename=tempfileplot,height=400,width=800)
plot(iris$Petal.Length,iris$Sepal.Width,col=iris$Species,pch=18,cex=4)
dev.off()

image_array = aperm(png::readPNG(tempfileplot),c(2,1,3))
scene = scene %>%
  add_object(xy_rect(x=0,y=1.1,z=0,xwidth=2,angle = c(0,180,0),
                     material = diffuse(image_texture = image_array)))
render_scene(scene,fov=20,parallel=TRUE,samples=500)


#Move the camera

render_scene(scene,lookfrom = c(7,1.5,10),lookat = c(0,0.5,0),fov=15,parallel=TRUE)
```

```
#Change the background gradient to a night time ambiance

render_scene(scene,lookfrom = c(7,1.5,10),lookat = c(0,0.5,0),fov=15,
             backgroundhigh = "#282375", backgroundlow = "#7e77ea", parallel=TRUE,
             samples=500)


#Increase the aperture to blur objects that are further from the focal plane.

render_scene(scene,lookfrom = c(7,1.5,10),lookat = c(0,0.5,0),fov=15,
             aperture = 0.5,parallel=TRUE,samples=500)


#We can also capture a 360 environment image by setting `fov = 360` (can be used for VR)

generate_cornell() %>%
  add_object(ellipsoid(x=555/2,y=100,z=555/2,a=50,b=100,c=50,
             material = metal(color="lightblue"))) %>%
  add_object(cube(x=100,y=130/2,z=200,xwidth = 130,ywidth=130,zwidth = 130,
                  material=diffuse(checkercolor="purple",
                                   checkerperiod = 30),angle=c(0,10,0))) %>%
  add_object(pig(x=100,y=190,z=200,scale=40,angle=c(0,30,0))) %>%
  add_object(sphere(x=420,y=555/8,z=100,radius=555/8,
                    material = dielectric(color="orange"))) %>%
  add_object(xz_rect(x=555/2,z=555/2, y=1,xwidth=555,zwidth=555,
                     material = glossy(checkercolor = "white",
                                       checkerperiod=10,color="dodgerblue"))) %>%
  render_scene(lookfrom=c(278,278,30), lookat=c(278,278,500), clamp_value=10,
               fov = 360,  samples = 500, width=800, height=400)


#Spin the camera around the scene, decreasing the number of samples to render faster. To make
#an animation, specify the a filename in `render_scene` for each frame and use the `av` package
#or ffmpeg to combine them all into a movie.

t=1:30
xpos = 10 * sin(t*12*pi/180+pi/2)
zpos = 10 * cos(t*12*pi/180+pi/2)

#Save old par() settings
old.par = par(no.readonly = TRUE)
on.exit(par(old.par))
par(mfrow=c(5,6))
for(i in 1:30) {
 render_scene(scene, samples=16,
   lookfrom = c(xpos[i],1.5,zpos[i]),lookat = c(0,0.5,0), parallel=TRUE)
}
```

r_obj *R 3D Model*

Description

3D obj model of the letter R, to be used with ‘obj_model()‘

Usage

```
r_obj()
```

Value

File location of the R.obj file (saved with a .txt extension)

Examples

```
#Load and render the included example R object file.

generate_ground(material = diffuse(noise = TRUE, noisecolor = "grey20")) %>%
  add_object(sphere(x = 2, y = 3, z = 2, radius = 1,
                    material = light(intensity = 10))) %>%
  add_object(obj_model(r_obj(), y = -1, material = diffuse(color="red"))) %>%
  render_scene(parallel=TRUE, lookfrom = c(0, 1, 10), clamp_value = 5, samples = 200)
```

`segment` *Segment Object*

Description

Similar to the cylinder object, but specified by start and end points.

Usage

```
segment(
  start = c(0, -1, 0),
  end = c(0, 1, 0),
  radius = 0.1,
  phi_min = 0,
  phi_max = 360,
  from_center = TRUE,
  direction = NA,
  material = diffuse(),
  capped = TRUE,
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

start	Default ‘c(0, -1, 0)‘. Start point of the cylinder segment, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cylinder segment, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘1‘. Radius of the segment.
phi_min	Default ‘0‘. Minimum angle around the segment.
phi_max	Default ‘360‘. Maximum angle around the segment.
from_center	Default ‘TRUE‘. If orientation specified via ‘direction‘, setting this argument to ‘FALSE‘ will make ‘start‘ specify the bottom of the segment, instead of the middle.
direction	Default ‘NA‘. Alternative to ‘start‘ and ‘end‘, specify the direction (via a length-3 vector) of the segment. Segment will be centered at ‘start‘, and the length will be determined by the magnitude of the direction vector.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
capped	Default ‘TRUE‘. Whether to add caps to the segment. Turned off when using the ‘light()‘ material.
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the segment. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the segment in the scene.

Examples

```
#Generate a segment in the cornell box.

generate_cornell() %>%
  add_object(segment(start = c(100, 100, 100), end = c(455, 455, 455), radius = 50)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)


# Draw a line graph representing a normal distribution, but with metal:
xvals = seq(-3, 3, length.out = 30)
yvals = dnorm(xvals)

scene_list = list()
for(i in 1:(length(xvals) - 1)) {
  scene_list[[i]] = segment(start = c(555/2 + xvals[i] * 80, yvals[i] * 800, 555/2),
                            end = c(555/2 + xvals[i + 1] * 80, yvals[i + 1] * 800, 555/2),
                             radius = 10,
                             material = metal())
}
```

```
scene_segments = do.call(rbind,scene_list)

generate_cornell() %>%
  add_object(scene_segments) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)


#Draw the outline of a cube:

cube_outline = segment(start = c(100, 100, 100), end = c(100, 100, 455), radius = 10) %>%
  add_object(segment(start = c(100, 100, 100), end = c(100, 455, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 100), end = c(455, 100, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 455), end = c(100, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 455), end = c(455, 100, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 455), end = c(100, 455, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 455), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 455, 100), end = c(455, 100, 100), radius = 10)) %>%
  add_object(segment(start = c(455, 455, 100), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 100, 100), end = c(455, 100, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 100, 455), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 100), end = c(455, 455, 100), radius = 10))


generate_cornell() %>%
  add_object(cube_outline) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)


#Shrink and rotate the cube

generate_cornell() %>%
  add_object(group_objects(cube_outline, pivot_point = c(555/2, 555/2, 555/2),
                           angle = c(45,45,45), scale = c(0.5,0.5,0.5))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

sphere *Sphere Object*

Description

Sphere Object

Usage

```
sphere(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the sphere.
`y`	Default ‘0‘. y-coordinate of the center of the sphere.
`z`	Default ‘0‘. z-coordinate of the center of the sphere.
`radius`	Default ‘1‘. Radius of the sphere.
`material`	Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the sphere in the scene.

Examples

```
#Generate a sphere in the cornell box.

generate_cornell() %>%
  add_object(sphere(x = 555/2, y = 555/2, z = 555/2, radius = 100)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, clamp_value = 5)


#Generate a gold sphere in the cornell box

generate_cornell() %>%
  add_object(sphere(x = 555/2, y = 100, z = 555/2, radius = 100,
                    material = microfacet(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, clamp_value = 5)
```

`text3d` *Text Object*

Description

Text Object

Usage

```
text3d(
  label,
  x = 0,
  y = 0,
  z = 0,
  text_height = 1,
  orientation = "xy",
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`label`	Text string.
`x`	Default '0'. x-coordinate of the center of the label.
`y`	Default '0'. y-coordinate of the center of the label.
`z`	Default '0'. z-coordinate of the center of the label.
`text_height`	Default '1'. Height of the text.
`orientation`	Default 'xy'. Orientation of the plane. Other options are 'yz' and 'xz'.
`material`	Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default 'c(0, 0, 0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.
`order_rotation`	Default 'c(1, 2, 3)'. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default 'FALSE'. Whether to flip the normals.
`scale`	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the text in the scene.

Examples

```
#Generate a label in the cornell box.

generate_cornell() %>%
  add_object(text3d(label="Cornell Box", x=555/2,y=555/2,z=555/2,text_height=60,
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
  render_scene(samples=500, clamp_value=10)

#Change the orientation
generate_cornell() %>%
  add_object(text3d(label="YZ Plane", x=550,y=555/2,z=555/2,text_height=100,
                    orientation = "yz",
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
 add_object(text3d(label="XY Plane", z=550,y=555/2,x=555/2,text_height=100,
                    orientation = "xy",
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
 add_object(text3d(label="XZ Plane", z=555/2,y=5,x=555/2,text_height=100,
                    orientation = "xz",
                    material=diffuse(color="grey10"))) %>%
  render_scene(samples=500, clamp_value=10)

#Add an label in front of a sphere
generate_cornell() %>%
  add_object(text3d(label="Cornell Box", x=555/2,y=555/2,z=555/2,text_height=60,
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
  add_object(text3d(label="Sphere", x=555/2,y=100,z=100,text_height=30,
                    material=diffuse(color="white"), angle=c(0,180,0))) %>%
  add_object(sphere(y=100,radius=100,z=555/2,x=555/2,
                    material=glossy(color="purple"))) %>%
  add_object(sphere(y=555,radius=100,z=-1000,x=555/2,
                    material=light(intensity=100,
                                   spotlight_focus=c(555/2,100,100)))) %>%
  render_scene(samples=500, clamp_value=10)


#A room full of bees
bee_list = list()
for(i in 1:100) {
bee_list[[i]] = text3d("B", x=20+runif(1)*525, y=20+runif(1)*525, z=20+runif(1)*525,
                       text_height = 50, angle=c(0,180,0))
}
bees = do.call(rbind,bee_list)
generate_cornell() %>%
  add_object(bees) %>%
  render_scene(samples=500, clamp_value=10)
```

`triangle` *Triangle Object*

Description

Triangle Object

Usage

```
triangle(
  v1 = c(1, 0, 0),
  v2 = c(0, 1, 0),
  v3 = c(-1, 0, 0),
  n1 = rep(NA, 3),
  n2 = rep(NA, 3),
  n3 = rep(NA, 3),
  color1 = rep(NA, 3),
  color2 = rep(NA, 3),
  color3 = rep(NA, 3),
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  reversed = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`v1`	Default ‘c(1, 0, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the first triangle vertex.
`v2`	Default ‘c(0, 1, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the second triangle vertex.
`v3`	Default ‘c(-1, 0, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the third triangle vertex.
`n1`	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the first triangle vertex.
`n2`	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the second triangle vertex.
`n3`	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the third triangle vertex.
`color1`	Default ‘NA‘. Length-3 vector or string indicating the color associated with the first triangle vertex. If NA but other vertices specified, color inherits from material.
`color2`	Default ‘NA‘. Length-3 vector or string indicating the color associated with the second triangle vertex. If NA but other vertices specified, color inherits from material.
`color3`	Default ‘NA‘. Length-3 vector or string indicating the color associated with the third triangle vertex. If NA but other vertices specified, color inherits from material.

material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
reversed	Default ‘FALSE‘. Similar to the ‘flipped‘ argument, but this reverses the handedness of the triangle so it will be oriented in the opposite direction.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XZ plane in the scene.

Examples

```
#Generate a triangle in the Cornell box.

generate_cornell() %>%
  add_object(triangle(v1 = c(100, 100, 100), v2 = c(555/2, 455, 455), v3 = c(455, 100, 100),
                      material = diffuse(color = "purple"))) %>%
   render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
                ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)

#Pass individual colors to each vertex:

generate_cornell() %>%
  add_object(triangle(v1 = c(100, 100, 100), v2 = c(555/2, 455, 455), v3 = c(455, 100, 100),
                      color1 = "green", color2 = "yellow", color3 = "red")) %>%
   render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
                ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

xy_rect *Rectangular XY Plane Object*

Description

Rectangular XY Plane Object

Usage

```
xy_rect(
  x = 0,
  y = 0,
  z = 0,
  xwidth = 1,
  ywidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the rectangle.
`y`	Default ‘0‘. x-coordinate of the center of the rectangle.
`z`	Default ‘0‘. z-coordinate of the center of the rectangle.
`xwidth`	Default ‘1‘. x-width of the rectangle.
`ywidth`	Default ‘1‘. y-width of the rectangle.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XY plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.

generate_cornell() %>%
  add_object(xy_rect(x = 555/2, y = 100, z = 555/2, xwidth = 200, ywidth = 200,
             material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800), lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

```
#Generate a gold plane in the cornell box

generate_cornell() %>%
  add_object(xy_rect(x = 555/2, y = 100, z = 555/2,
                     xwidth = 200, ywidth = 200, angle = c(0, 30, 0),
                     material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

xz_rect *Rectangular XZ Plane Object*

Description

Rectangular XZ Plane Object

Usage

```
xz_rect(
  x = 0,
  xwidth = 1,
  z = 0,
  zwidth = 1,
  y = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the rectangle.
xwidth	Default ‘1‘. x-width of the rectangle.
z	Default ‘0‘. z-coordinate of the center of the rectangle.
zwidth	Default ‘1‘. z-width of the rectangle.
y	Default ‘0‘. y-coordinate of the center of the rectangle.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XZ plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.

generate_cornell() %>%
  add_object(xz_rect(x = 555/2, y = 100, z = 555/2, xwidth = 200, zwidth = 200,
             material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)


#Generate a gold plane in the cornell box

generate_cornell() %>%
  add_object(xz_rect(x = 555/2, y = 100, z = 555/2,
             xwidth = 200, zwidth = 200, angle = c(0, 30, 0),
             material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

`yz_rect` *Rectangular YZ Plane Object*

Description

Rectangular YZ Plane Object

Usage

```
yz_rect(
  x = 0,
  y = 0,
  z = 0,
  ywidth = 1,
  zwidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the rectangle.
`y`	Default ‘0‘. y-coordinate of the center of the rectangle.
`z`	Default ‘0‘. z-coordinate of the center of the rectangle.
`ywidth`	Default ‘1‘. y-width of the rectangle.
`zwidth`	Default ‘1‘. z-width of the rectangle.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the YZ plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.

generate_cornell() %>%
  add_object(yz_rect(x = 100, y = 100, z = 555/2, ywidth = 200, zwidth = 200,
                     material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)

#Generate a gold plane in the cornell box

generate_cornell() %>%
  add_object(yz_rect(x = 100, y = 100, z = 555/2,
                     ywidth = 200, zwidth = 200, angle = c(0, 30, 0),
                     material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 400, parallel = TRUE, clamp_value = 5)
```

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